

AIRCRAFT COMMUNITY NOISE IMPACT STUDIES

JANUARY 1977

PREPARED UNDER CONTRACT NAS 1-14488

BY

DOUGLAS AIRCRAFT COMPANY
MCDONNELL DOUGLAS CORPORATION
LONG BEACH, CALIFORNIA

FOR



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Langley Research Center
Hampton, Virginia

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FOREWORD

This document presents the results of a study entitled "Aircraft Community Noise Impact Studies" performed for NASA under contract NAS1-14488 by the Douglas Aircraft Company, McDonnell Douglas Corporation (MDC).

The NASA technical monitor for the study was J. W. Cawthorn, Acoustics and Noise Reduction Division, Langley Research Center, Hampton, Virginia. The MDC effort was under the overall direction of R. D. FitzSimmons, Director, Advanced Supersonic Transport. The Technical Manager was W. T. Rowe.

This report includes the results of in-depth analyses to estimate noise levels and community noise contours for two supersonic cruise vehicle designs - one powered by four turbojet engines integrated into the MDC baseline airplane and the other powered by four Pratt & Whitney VSCE 502B engines integrated into the MDC baseline airplane - and by the DC-8-61 aircraft now in commercial service.

Primary units are International Units with conversion to U.S. Units.

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SYMBOLS AND ABBREVIATIONS

A	Area
CAN	Committee on Aircraft Noise
°C	Temperature - Degrees Celsius
DAC	Douglas Aircraft Company
dB(A)	A-Weighted Sound Pressure Level, decibels
°	Degrees
EAS	Equivalent Airspeed
EPNL	Effective Perceived Noise Level, decibels
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
Ft, ft	Feet
fps	Feet per second
°F	Temperature - Degrees Fahrenheit
GE	General Electric Corporation
ICAO	International Civil Aviation Organization
in	Inches
°K	Temperature - Degrees Kelvin
KEAS	Equivalent Airspeed, Knots
kg	Kilograms
km	Kilometers
KT	Knots
LAX	Los Angeles International Airport
LB, lb	Pounds
m	Meters
MDC	McDonnell Douglas Corporation
MPT	Multiple-pure-tone
N	Newtons
NASA	National Aeronautics and Space Administration
N.Mi., n.mi.	Nautical Miles
NEF	Noise Exposure Forecast
PNL	Perceived Noise Levels, decibels
PNLT	Tone Corrected Perceived Noise Level, decibels
P&WA	Pratt & Whitney Aircraft

SYMBOLS AND ABBREVIATIONS (Concluded)

rad	Radian
SCAR	Supersonic Cruise Aircraft Research
sec, s	Seconds
SL	Sea Level
SLS	Sea Level Static
SST	Supersonic Transport
Std	Standard
US	United States of America
V	Velocity
V _{MU}	Airplane Speed for Minimum Unstick, Established by the Ground Angle Limit Clearance for Rotation
V _{ZRC}	Airplane Speed for Zero Rate of Climb, One Engine Out With Gear Up and Out of Ground Effect
V ₂	Airplane Speed at the 10.7 meter (35 foot) Obstacle
VSCE	Variable Stream Control Engine
W	Weight Flow
%	Percent

SUBSCRIPTS

F	Fan
i	Ideal
L0	Liftoff
MIX	Mixed
P	Primary
T	Total

1.0 INTRODUCTION

The National Aeronautics and Space Administration (NASA) is sponsoring a continuing program of supersonic cruise aircraft research (SCAR). The McDonnell Douglas Corporation has participated in this effort since 1972. A study conducted in 1973 defined a baseline airplane configuration which was integrated with dry turbojet engines fitted with jet noise suppressors, (Reference 1). As a part of the SCAR program, studies are continuing by both major U.S. engine manufacturers (General Electric and Pratt & Whitney Aircraft) to define and refine the engine cycle for advanced technology development (References 2 and 3). MDC has continued to integrate candidate engines of the two manufacturers in the baseline airplane.

The engine study portion of the SCAR program has progressed to the point that both engine manufacturers are ready to initiate a demonstration of advanced technology items such as duct burning, multiple valving and low emission burners. Each manufacturer has screened various engine cycle concepts and has arrived at its version of a variable cycle engine. Characteristic of these engines is a coannular noise benefit which is defined by General Electric and Pratt & Whitney as the difference in noise level between the total noise which would be predicted for coaxial nozzles with an inverted velocity profile and the noise estimated by scaling measured model scale data to full scale. Coannular noise benefits of up to 10 PNdB have been predicted by the two engine manufacturers (Reference 4). The initial MDC SCAR baseline airplane configuration (Reference 1) features four dry turbojet engines. These engines incorporate movable mechanical jet noise suppressors to meet or slightly better the current FAR Part 36 requirements for sideline and takeoff noise. The noise level at approach is assumed to be less than, or equal to, 108 EPNdB. The jet noise suppressor concept is based on extensive recent model scale development and static testing by the engine companies and one aircraft manufacturer under the sponsorship of the FAA. (References 5 and 6). Limited full scale static tests confirm the model scale results. This engine and associated suppressor are sufficiently developed that the combination is the logical candidate for a near term advanced supersonic airplane program in contrast to the advanced technology engines

with the coannular benefit which are projected for 1985 technology readiness.

In view of the community concern regarding the introduction of any new aircraft into service, the noise characteristics of airplanes designed for supersonic cruise and powered by advanced technology engines require assessment of the impact on the community in the vicinity of airports. Previous MDC in-house studies have shown that dual valve variable cycle engines without the coannular noise benefit produce community noise levels up to 5 PNdB higher than equivalent suppressed turbojet or mini-bypass engines. Another study (Reference 7) examined the potential reduction of aircraft noise impact that can be achieved by flight operational techniques of STOL aircraft.

The objectives of this study are to: (1) conduct a program to determine the community noise impact of advanced technology engines when installed in a supersonic aircraft, (2) determine the potential reduction of community noise by flight operational techniques for the study aircraft, (3) estimate the community noise impact of the study aircraft powered by suppressed turbojet engines and by advanced duct heating turbofan engines, and (4) compare the impact of the two supersonic designs with that of conventional commercial DC-8 aircraft.

2.0 TECHNICAL APPROACH

The technical approach taken in this study is described.

1. Modify the noise level predictions for the MDC baseline airplane with suppressed turbojet engines (Reference 1) to include peak A-weighted sound pressure levels. Predict the peak dB(A) variation with distance for several power levels.
2. Determine the P&WA duct burning turbofan (VSCE 502B) engine exhaust velocity and temperature data.
3. Calculate the effects of an ejector on VSCE 502B engine and nozzle performance.
4. Predict noise level variation with distance in terms of EPNdB and dB(A) at several power levels for the MDC baseline airplane with VSCE 502B engines.
5. Determine landing and takeoff flight paths for both supersonic aircraft configurations operating at maximum landing and takeoff gross weights and for the DC-8-61 aircraft operating at maximum landing and takeoff gross weights and at a typical mission gross weight. The typical mission is defined as 1852 km(1000 n.mi) stage length with a 60 percent load factor. Straight flight paths only are considered in the study.
6. Estimate FAR Part 36 noise levels for all study aircraft flight paths.
7. Calculate community noise contours for all study aircraft flight paths to determine the flight path with the minimum noise contour for each aircraft/engine configuration.

3.0 SUMMARY

The results of a study to estimate the community noise impact of two SCAR configurations are reported herein. The first SCAR configuration, designated the SCAR turbojet, is the MDC baseline airplane integrated with four dry turbojet engines using mechanical jet noise suppressors. The second SCAR configuration, designated the SCAR VSCE, is the MDC baseline airplane integrated with four P&WA VSCE 502B engines. The latter engines utilize the recently defined coannular noise benefit.

The turbojet engine data available from a previous program are utilized to predict the SCAR turbojet configuration EPNL and peak dB(A) noise level variations with distance for several power settings. Similarly, the VSCE 502B engine exhaust system data determined in this study are employed to predict the SCAR VSCE configuration EPNL and peak dB(A) noise level variations with distance for several power settings. Estimates for the effect of the coannular noise benefit are included in the SCAR VSCE configuration noise level predictions.

Several takeoff and approach flight paths and methods of aircraft operation are studied for the SCAR configurations to identify promising candidates for noise abatement. Flight paths for the DC-8-61 aircraft operating at maximum landing and takeoff gross weights and at typical mission landing and takeoff gross weights are evaluated. Noise estimates at FAR Part 36 locations are made for the three aircraft. Takeoff noise contours are determined for all flight paths at the 90 EPNdB, 100 EPNdB and 110 EPNdB levels. Community noise contours are calculated for selected combinations of the takeoff and approach flight paths for the three aircraft.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Conclusions drawn from this study are presented.

1. For both SCAR configurations studied, one takeoff procedure produces the lowest noise levels of any procedure conforming to the FAR Part 36 rules at 6.5 km (3.5 n.mi.). This procedure features cutback initiated at 335 m, (1100 ft), aircraft speed held at $V_2 + 10$ KEAS until the noise level is 10 PNdB down from the highest level at the monitor, increase of thrust to takeoff power, acceleration at 0.61 m/s^2 (2 fps^2) to 250 KEAS and climb at 250 KEAS to 5180 m (17,000 ft) altitude.
2. Of the four takeoff procedures studied for both SCAR configurations, the procedure at full takeoff power with no cutback produces the smallest 90 EPNdB and 100 EPNdB community noise level contour areas.
3. Of the additional takeoff procedures studied for the SCAR turbojet configuration, a procedure with cutback 3 sec prior to the monitor and high aircraft acceleration gives the minimum 90 EPNdB and 100 EPNdB community contour areas of all takeoff flight paths studied. From this result, it can be inferred that a takeoff without cutback and with maximum aircraft acceleration including early flap retraction should give the smallest possible 90 EPNdB and 100 EPNdB contour areas for the SCAR turbojet configuration.
4. Retraction of the jet noise suppressors in the turbojet configuration to permit increasing the engine power setting and improving the climb gradient is not attractive as a noise abatement procedure.
5. For both SCAR configurations, the 2-segment approach flight path produces the smallest 90 EPNdB community noise level contour area

of any of the approaches studied. The areas for the 2-segment approach at the 100 EPNdB and 110 EPNdB levels are only slightly larger than the areas for the decelerating approach studied.

6. Using the takeoff procedure noted in subparagraph 1 above, the area within the 90 EPNdB community noise contour for the turbojet configuration is approximately 24 percent greater than the area for the DC-8-61 aircraft operating at maximum takeoff gross weight and the equivalent area for the VSCE configuration is approximately 84 percent greater than the area for the DC-8-61 operating at maximum takeoff gross weight.
7. For equal maximum takeoff gross weight with takeoffs as noted in subparagraph 1 above, the area within the 90 EPNdB contour for the turbojet aircraft is approximately 87.3 km^2 (25.5 n.mi.^2) compared to approximately 129.8 km^2 (37.8 n.mi.^2) for the VSCE aircraft or almost 50 percent larger. The range of the VSCE aircraft is 30 percent greater than the range of the turbojet aircraft. For equal ranges, resizing the VSCE airplane and engine would be required which could provide some improvement in its contour.
8. The areas within the 100 EPNdB and 110 EPNdB contours for the VSCE are also larger than the respective areas for the turbojet configuration.
9. The results of the study illustrate that a takeoff procedure with a thrust cutback to meet a noise level requirement at a monitor near the airport produces a larger 90 EPNdB community noise contour area than a procedure with a full power takeoff without cutback.

4.2 Recommendations

On the basis of the results of this study, the following recommendations are made:

1. The community noise impact study of SCAR aircraft should be extended to cover additional flight procedures including early, programmed flap retraction and programmed thrust changes at various points in the takeoff to determine the impact on community noise. These procedures can be tailored for specific airports to minimize community annoyance, as noted below.
2. The study should also be extended to include selected specific airports from which these aircraft could be expected to operate and the actual population density surrounding the airports used. The number of people exposed and annoyed based on the anticipated noise exposure forecast (NEF) should be determined. Curved flight paths should be employed in the extended study to assess the impact on community noise and to illustrate the flight paths with minimum annoyance.
3. Considerations of community noise impact and the relative performance of specific advanced technology engines under study should be included in the evaluation process for each engine cycle.
4. The development of advanced technology mechanical jet noise suppressors should be continued through a flight test demonstration to validate the noise estimates made herein.
5. The development of coaxial nozzles designed to produce the coannular noise benefit should be continued through a flight test demonstration to validate the noise estimates made herein.

5.0 ENGINE PERFORMANCE ANALYSIS

The dry turbojet engine data needed to predict the EPNL and peak dB(A) noise level variations with distance for the MDC turbojet aircraft are available from a previous study (Reference 1). The steps followed to generate the VSCE 502B engine performance data required to predict the EPNL and peak dB(A) noise level variations with distance for the VSCE configuration are summarized in Sections 5.1 through 5.3.

5.1 Basic P&WA VSCE 502B Data

Data are supplied by P&WA on the VSCE 502B engine in the form of a data pack. Data at specific operating conditions are selected for this study.

1. Sea level, 0.3 Mach, std. + 10°C (18°F) day, power settings of maximum augmentation, partial augmentation (3 points) and maximum dry.
2. 1219 m (4000 ft) altitude, 0.5 Mach, std. + 10°C (18°F) day, power settings same as above.
3. 4573 m (15,000 ft) altitude, 0.7 Mach, std. day, power settings same as above.
4. 113 m (370 ft) altitude, 0.223 Mach, std. + 10°C (18°F) day, power settings of maximum dry, 95.7%, 60%, 40% and 20% of maximum dry.

Basically the data conform to DAC installation requirements, including air-flow schedule, airbleed and power extraction. The data are adjusted for small variations in inlet pressure recovery, with P&WA's cognizance and concurrence.

5.2 Calculated Data for the P&WA VSCE 502B Engine

The following data are calculated for the VSCE 502B engine at all the flight conditions described in Paragraph 5.1:

1. Average velocity at ejector exit plane.
2. Weight flow at ejector plane.
3. Ejector exit area.

The results are summarized in Table 1. For the cases designated "mixing cases", the characteristics of the exhaust stream mixed with secondary air are also predicted at the ejector exit plane. Velocity profiles for the "mixing cases" are shown in Figures 1 through 4.

TABLE 1 - SCAR VSCE 502B - EJECTOR NOZZLE
PERFORMANCE SUMMARY
(S. I. UNITS)

FLIGHT CONDITION Power Code	SEA LEVEL, 0.3 M STD + 10°C DAY					1219 m, 0.5 M STD + 10°C DAY					4572 m, 0.7 M STD + 10°C DAY					112.8 m, 0.223 M STD + 10°C DAY				
	1*	2	3	4	10	1	2	3	4*	10	11	12	13	14*	20	10	31	32	33*	34
W_P ($\frac{kg}{sec}$)	181.85	181.85	181.85	181.85	181.85	174.71	174.71	174.71	174.71	174.71	142.74	142.74	142.74	142.74	142.74	166.23	159.98	138.33	112.01	79.66
W_F ($\frac{kg}{sec}$)	241.29	238.97	235.49	233.17	232.01	231.75	229.53	226.18	223.96	222.84	174.28	172.61	170.09	168.41	167.58	223.75	214.17	191.54	160.30	121.30
W_T ($\frac{kg}{sec}$)	423.14	420.82	417.34	415.02	413.86	406.46	404.23	400.89	398.66	397.55	317.02	315.34	312.83	311.15	310.32	389.98	374.15	329.87	272.31	200.96
V_{P_i} ($\frac{m}{sec}$)	554.7	554.7	554.7	554.7	554.7	588.3	588.3	588.3	588.3	588.3	748.9	748.9	748.9	748.9	748.9	528.8	402.3	319.1	247.8	170.1
V_{F_i} ($\frac{m}{sec}$)	1015.0	931.8	769.0	617.2	516.6	1036.6	951.3	784.6	629.1	526.1	1088.4	997.0	818.4	652.0	541.6	498.3	482.2	445.9	391.1	302.4
V_i ($\frac{m}{sec}$)	817.2	768.7	675.7	589.8	533.4	843.7	794.3	698.9	611.1	553.5	935.4	884.8	786.7	696.5	637.0	511.5	448.1	392.9	332.3	249.9
A_{P_i} (m^2)	0.7413	0.7413	0.7413	0.7413	0.7413	0.7452	0.7452	0.7452	0.7452	0.7452	0.7071	0.7071	0.7071	0.7071	0.7071	0.7045	0.8458	0.8819	0.8845	0.8813
A_{F_i} (m^2)	0.9161	0.8226	0.6529	0.5084	0.4194	0.9555	0.8574	0.680	0.529	0.4361	1.0019	0.8968	0.7071	0.5465	0.4477	0.4155	0.4077	0.3923	0.3729	0.3619
A_{T_i} (m^2)	1.6574	1.5639	1.3942	1.2497	1.1606	1.7006	1.6026	1.4252	1.2742	1.1813	1.709	1.6039	1.4142	1.2535	1.1548	1.120	1.2535	1.2742	1.2574	1.2432
$\bar{V}_{mix}$ ($\frac{m}{sec}$)	589.2								506.9					598.0					254.8	
A_{mix} (m^2)	3.0813								1.8761					1.7116					2.1258	
$\bar{V}_{mix}/V_i$	0.72								0.83					0.86					0.77	
A_{mix}/A_{T_i}	1.86								1.47					1.37					1.69	
W_{Tmix}/W_T	1.43								1.32					1.26					1.47	

*Mixing Cases

TABLE 1 (Continued) - SCAR VSCE 502B - EJECTOR NOZZLE PERFORMANCE SUMMARY
(U.S. UNITS)

FLIGHT CONDITION	Power Code	SEA LEVEL, 0.3 M STD + 18°F DAY					4000 FT, 0.5 M STD + 18°F DAY					15,000 FT, 0.7 M STD + 18°F DAY					370 FT, 0.223 M STD + 18°F DAY				
		1*	2	3	4	10	1	2	3	4*	10	11	12	13	14*	20	10	31	32	33*	34
W_p ($\frac{LB}{sec}$)		400.9	400.9	400.9	400.9	400.9	385.16	385.16	385.16	385.16	385.16	314.68	314.68	314.68	314.68	314.68	366.47	352.70	304.96	246.94	175.62
W_F ($\frac{LB}{sec}$)		531.96	526.84	519.17	514.06	511.50	510.93	506.02	498.65	493.74	491.28	384.22	380.53	374.99	371.29	369.45	493.29	472.16	422.27	353.40	267.41
W_T ($\frac{LB}{sec}$)		932.86	927.74	920.07	914.96	912.40	896.09	891.18	883.81	878.90	876.44	698.90	695.21	689.67	685.97	684.13	859.76	824.86	727.23	600.34	443.03
W_{pi} ($\frac{FT}{sec}$)		1820	1820	1820	1820	1820	1930	1930	1930	1930	1930	2457	2457	2457	2457	2457	1735	1320	1047	813	558
V_{Fi} ($\frac{FT}{sec}$)		3330	3057	2523	2025	1695	3401	3121	2574	2064	1726	3571	3271	2685	2139	1777	1635	1582	1463	1283	992
$\bar{V}_i$ ($\frac{FT}{sec}$)		2681	2522	2217	1935	1750	2768	2606	2293	2005	1816	3069	2903	2581	2285	2090	1678	1470	1289	1090	820
A_{pi} (in^2)		1149	1149	1149	1149	1149	1155	1155	1155	1155	1155	1096	1096	1096	1096	1096	1092	1311	1367	1371	1366
A_{Fi} (in^2)		1420	1275	1012	788	650	1481	1329	1054	820	676	1553	1390	1096	847	694	644	632	608	578	561
A_{Ti} (in^2)		2569	2424	2161	1937	1799	2636	2484	2209	1975	1831	2649	2486	2192	1943	1790	1736	1943	1975	1949	1927
$\bar{V}_{mix}$ ($\frac{FT}{sec}$)		1933									1663				1962					836	
A_{mix} (in^2)		4776									2908				2653					3295	
$\bar{V}_{mix}/V_i$		0.72									0.83				0.86					0.77	
A_{mix}/A_{Ti}		1.86									1.47				1.37					1.69	
$W_{T_{mix}}/W_T$		1.43									1.32				1.26					1.47	

*Mixing Cases

FLIGHT CONDITION
 SEA LEVEL
 0.3 MACH
 STD + 10°C (18°F) DAY
 POWER CODE NO. 1

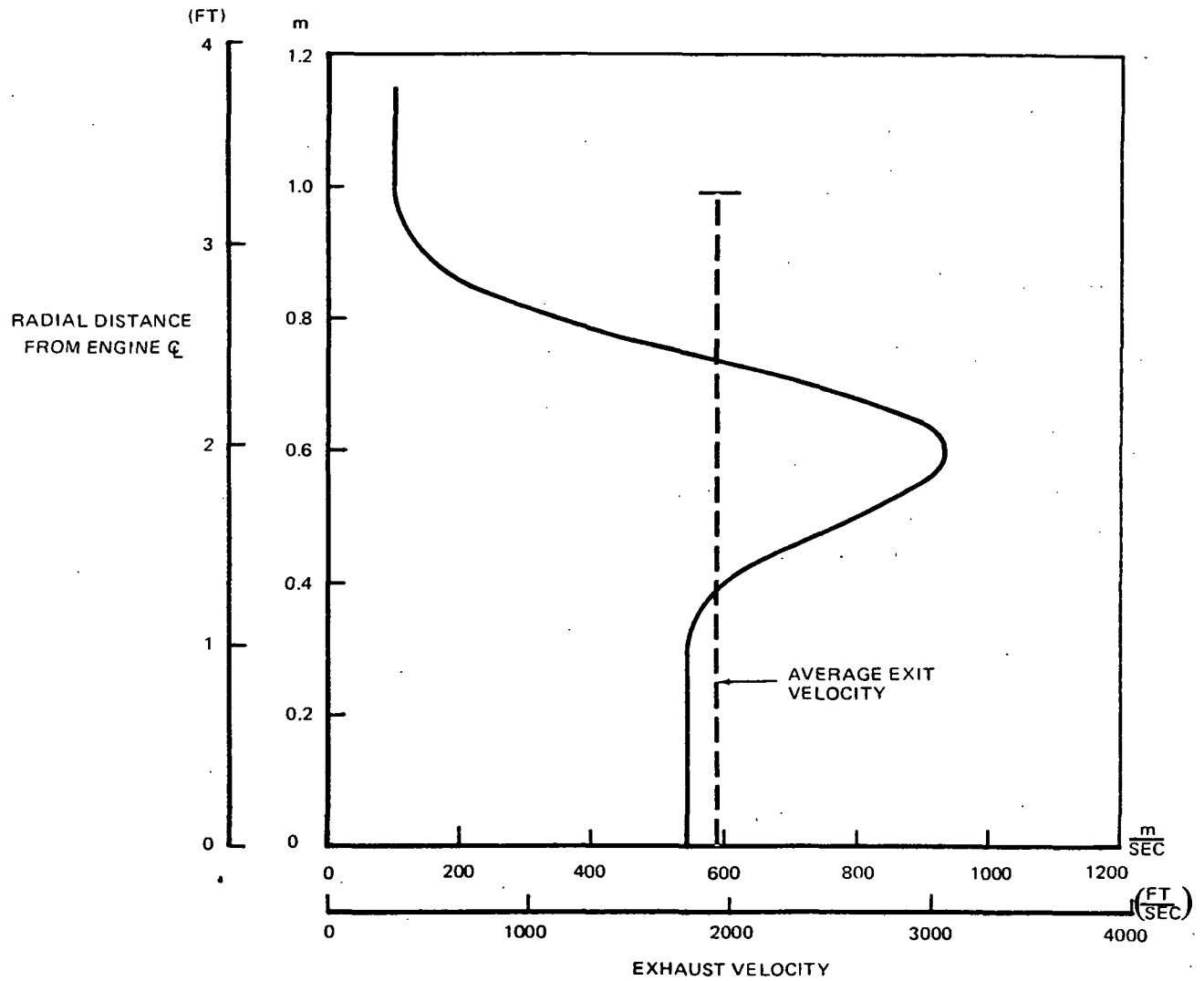


FIGURE 1. P&WA VSCE 502B – VELOCITY PROFILE AT EJECTOR EXIT PLANE

FLIGHT CONDITION
1219m (4000 FT) ALTITUDE
0.5 MACH
STD + 10°C (18°F) DAY
POWER CODE NO. 4

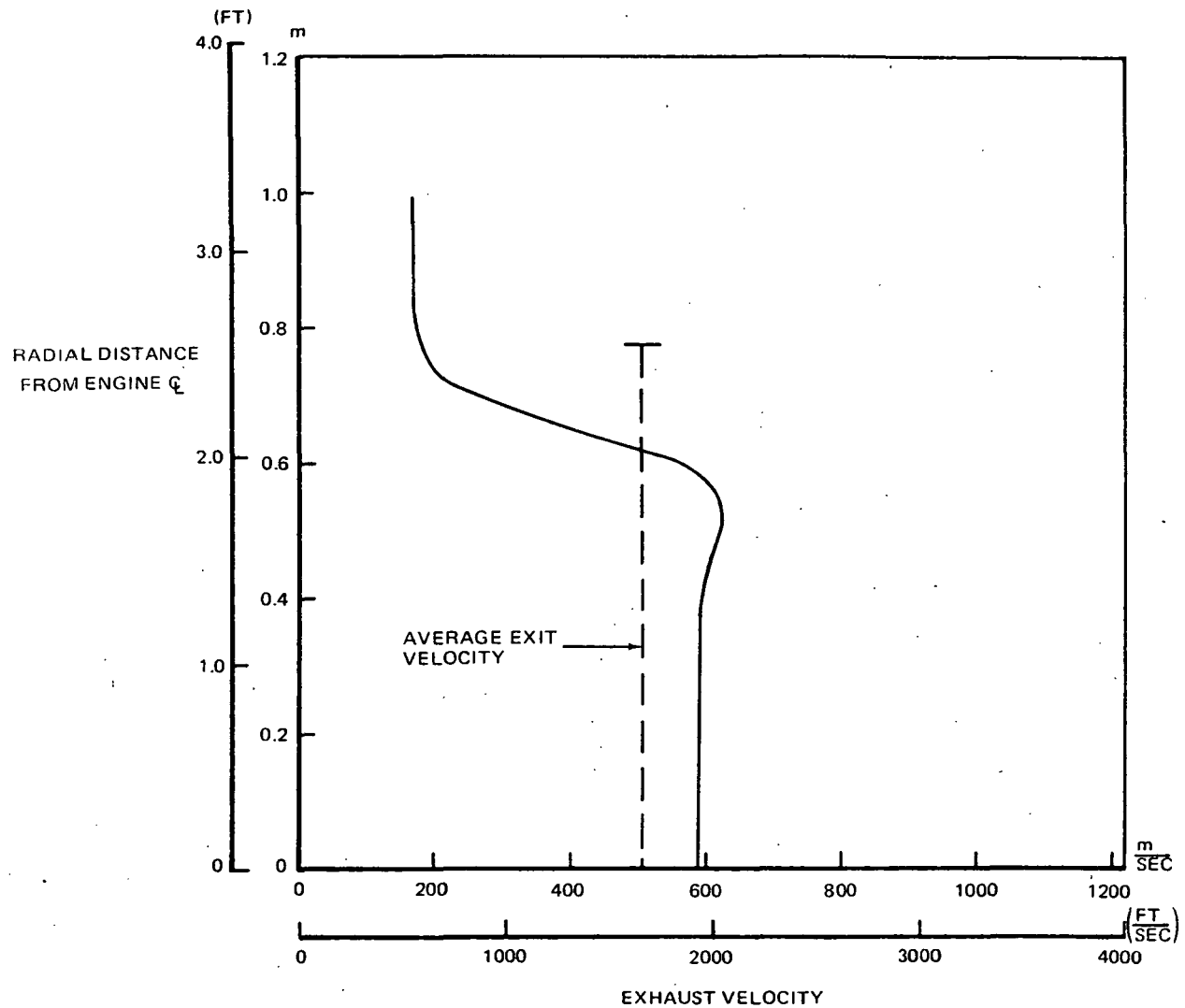


FIGURE 2. P&WA VSCE 502B – VELOCITY PROFILE AT EJECTOR EXIT PLANE

FLIGHT CONDITION
 4572m (15,000 FT) ALTITUDE
 0.70 MACH
 STD + 10°C (18°F) DAY
 POWER CODE NO. 14

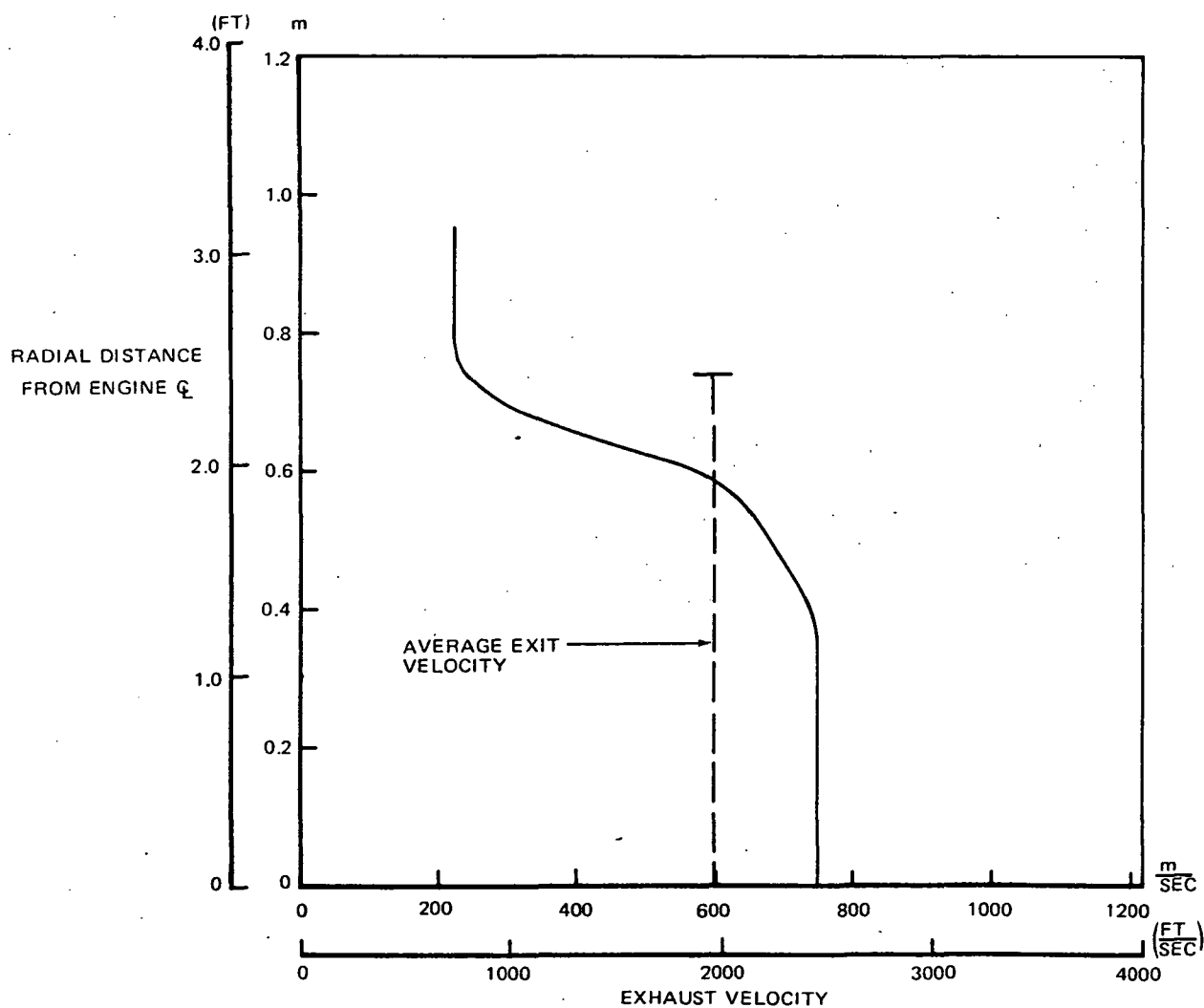


FIGURE 3. P&WA VSCE 502B – VELOCITY PROFILE AT EJECTOR EXIT PLANE

FLIGHT CONDITION

113m (370 FT) ALTITUDE

0.223 MACH

STD + 10°C (18°F) DAY

POWER CODE NO. 33

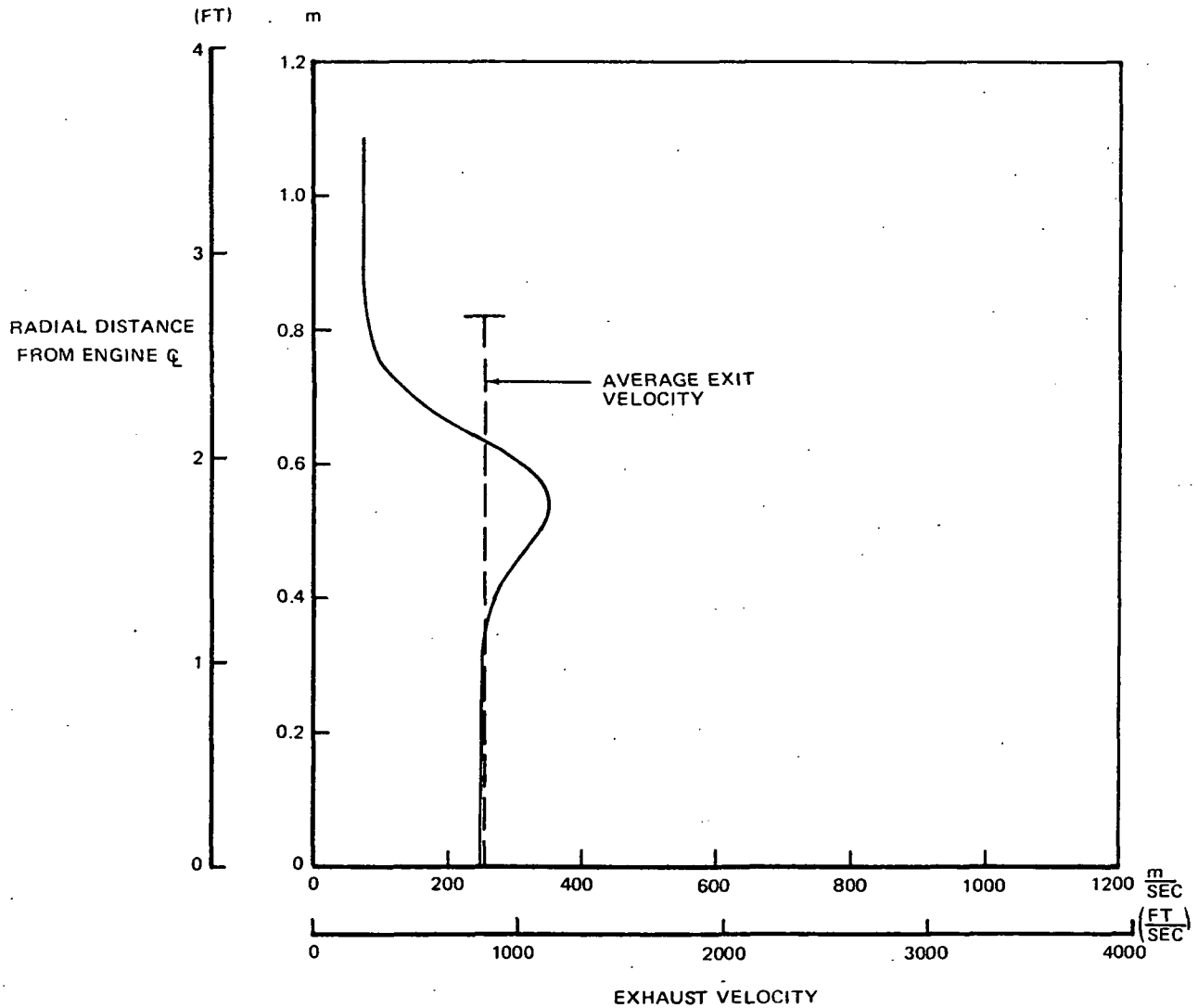


FIGURE 4. P&WA VSCE 502B – VELOCITY PROFILE AT EJECTOR EXIT PLANE

6.0 SCAR CONFIGURATION NOISE PREDICTIONS

6.1 Flyover Noise Predictions from Engine Component Data

Predictions of airplane flyover noise levels are made using engine thermodynamic, aerodynamic, and geometric parameters in conjunction with airplane performance data. A summary of the MDC component noise prediction method and specific procedures for compressor, jet and core noise is presented in this section.

6.1.1 Summary of Prediction Procedures. - Static engine noise levels are calculated by estimating the component noise source levels and spectra for the fan or compressor, turbine, core, and jet noise sources. The component noise levels for the fan inlet and fan exhaust include broadband noise, discrete tones, and multiple-pure-tone (MPT) inlet noise. Compressor noise consists primarily of discrete tones. Turbine noise includes high-frequency broadband noise and discrete tones. Core noise, which includes combustion and strut noise, consists of low-frequency broadband noise. Jet mixing noise includes low frequency broadband noise due to the mixing of the hot primary stream with the surrounding ambient air or with the bypass stream and the surrounding ambient air.

Contributions of the individual noise sources are calculated using an MDC - developed computerized procedure based on semi-empirical equations that relate the strength and the directivity of the far field noise levels to appropriate aerodynamic and geometric variables of various components of a propulsion system in a flight environment. The program uses a stage-stacking or component-building-block approach to estimate the noise produced by as many as 14 separate engine components. Any number of these components can be selected to fit a given engine configuration.

After inputs to the acoustic equations have been defined for a given engine configuration and operating point, the program calculates broadband noise, discrete tone, and multiple-pure-tone spectra as required for each engine component.

Each noise source prediction results in a 24×19 matrix of one-third-octave sound pressure levels for angles between 0 and π rad (0 and 180 degrees) from the inlet in 0.18 rad (10 degrees) increments at a 30.5 m (100 ft) polar radius. Attenuation spectra for each source are subtracted from untreated sound pressure level spectra to obtain sound pressure levels from inlet or exhaust ducts containing acoustically absorptive linings. Treated sound pressure levels for each component are extrapolated from the 30.5 m (100 ft) radius to the desired distance accounting for spherical divergence and atmospheric absorption. Sound pressure levels from all sources are combined on a mean-square-pressure basis to determine 1/3-octave-band sound pressure levels at each angle at the desired distance.

6.1.2 Compressor Noise. - The procedure used to predict the discrete tones from the compressor stages is based on the empirically derived method of Reference 8. Good agreement is shown in Reference 8 between predictions and measured data for several test cases.

6.1.3 Jet and Core Engine Noise. - Procedures described in Reference 9 are used to identify and correlate low frequency jet and core noise for low- and high-bypass-ratio engines with circular nozzles.

For coaxial nozzles, the jet noise is estimated by conventional methods. In advanced technology engines, the outer annulus flow rate and velocity are much higher than the inner core flow rate and velocity to take advantage of the coannular noise benefit to reduce jet noise. The state-of-the-art for estimating the level of this benefit is such that complete reliance must be placed on engine company static model scale data scaled to full size. The prediction procedure for estimating the jet noise levels in advanced technology engines with the coannular noise benefit consists of calculating the coaxial nozzle jet noise by conventional methods and applying a delta. The deltas to be applied have been previously determined as the difference between MDC jet noise estimates of coaxial nozzles without the coannular noise benefit and engine company estimates with the coannular noise benefit included.

For mechanically suppressed nozzles, the jet noise is estimated by the procedures described in Reference 1. A comparison between predicted and measured data for a multilobe suppressor is reproduced from Reference 1 and shown in Figure 5. These procedures are based on the theories developed in the FAA SST Follow-On Program (References 5 and 6).

6.2 Engine Noise Sources

6.2.1 Turbojet Engine Noise Sources. - The engine components employed for the dry turbojet engine include the compressor, core and jet noise sources for all power settings and non-propulsive noise is added to engine noise at approach power settings. Jet noise levels are predicted at high power settings with the jet noise suppressors deployed and with the suppressors stowed. Acoustic treatment is included in the inlet and the exhaust nozzle ejector. The inlet acoustic treatment is defined in Reference 10. At low power settings, the jet noise levels are predicted with the suppressors stowed.

6.2.2 VSCE 502B Engine Noise Sources. - The engine components employed for the VSCE 502B engine include the core, fan jet and primary jet noise sources for all power settings and non-propulsive noise is added at approach power settings. Insufficient information was available to estimate the fan turbomachinery noise and previous P&WA noise estimates had indicated that the VSCE 502B engine noise level was dominated by jet noise. Therefore, the fan turbomachinery noise was ignored.

6.3 Flyover Noise Prediction Results

6.3.1 MDC Turbojet Aircraft EPNL and Peak dB(A) Predictions. - The predicted relationship between the EPNL and distance at several levels of corrected engine thrust is shown in Figures 6 through 8 for the MDC baseline airplane integrated with 4 dry turbojet engines including jet noise suppressors. Figure 6 presents the predicted EPNL-distance relationship for high power settings with the jet noise suppressors stowed. Figure 7 illustrates the predicted EPNL-distance relationship for high power settings with the jet

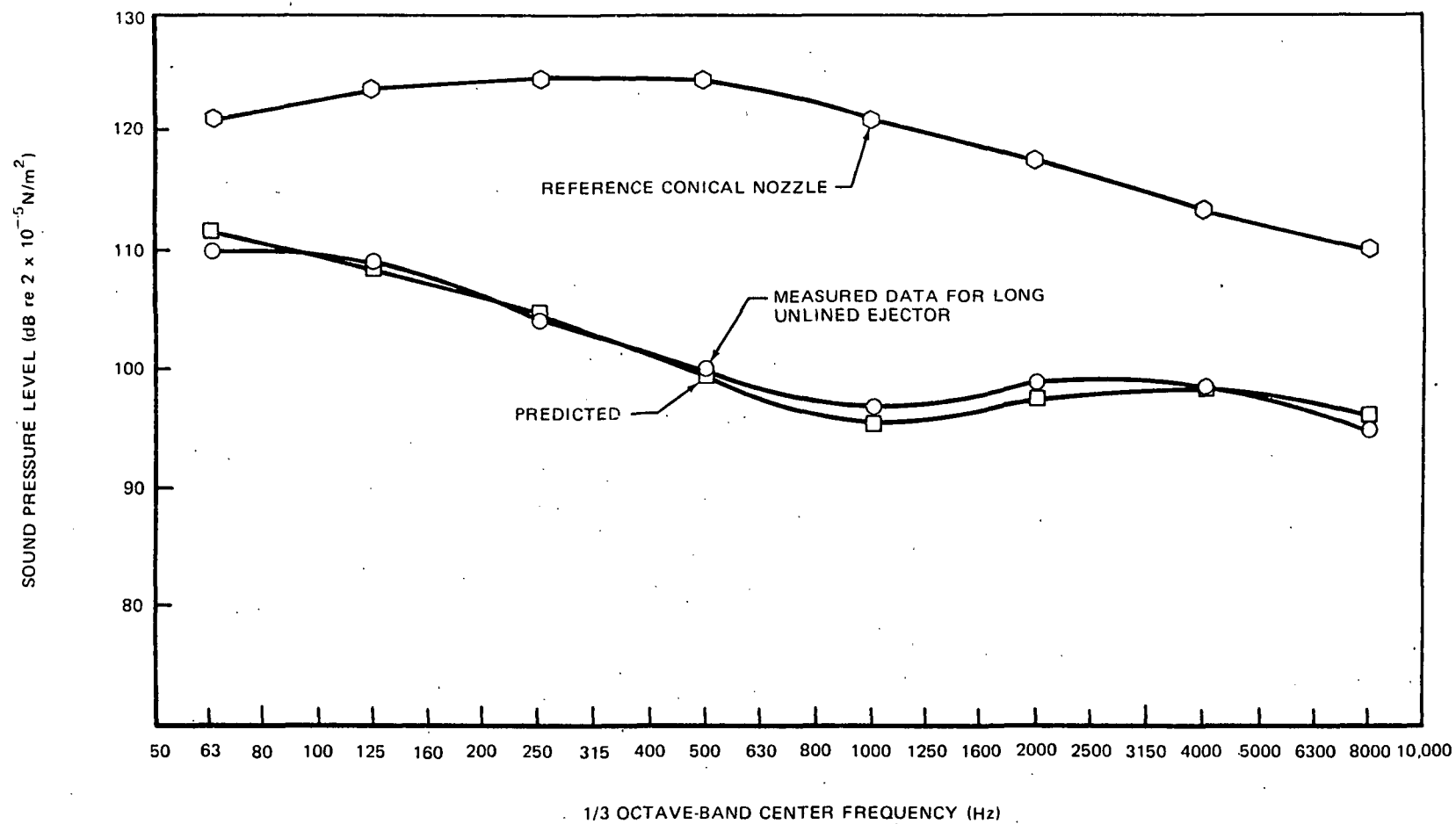


FIGURE 5. MEASURED AND PREDICTED NOISE LEVEL SPECTRA FOR A MULTILOBE FULL-SCALE JET NOISE SUPPRESSOR

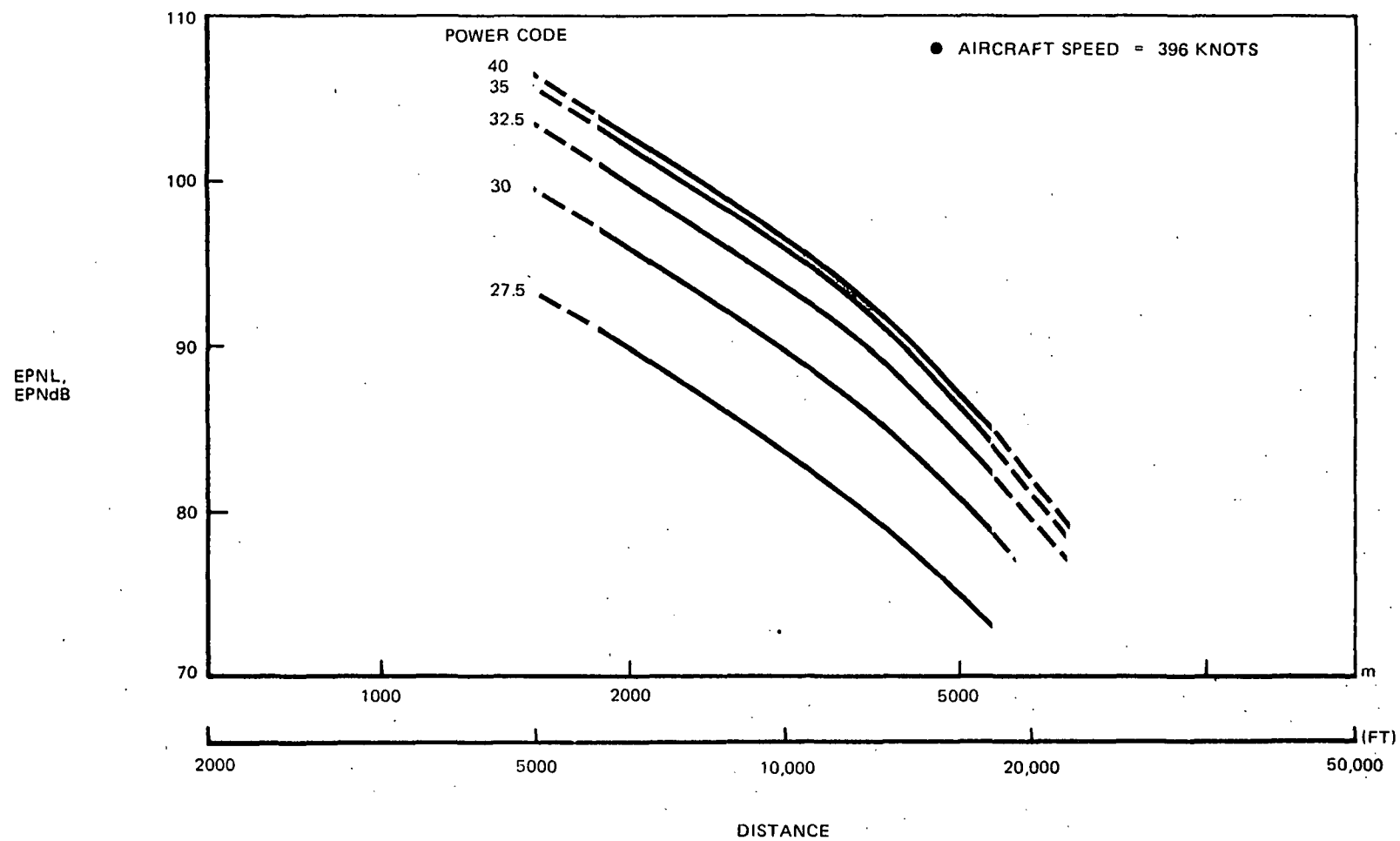


FIGURE 6. PREDICTED EPNL — DISTANCE VARIATIONS — MDC TURBOJET AIRCRAFT — SUPPRESSORS STOWED

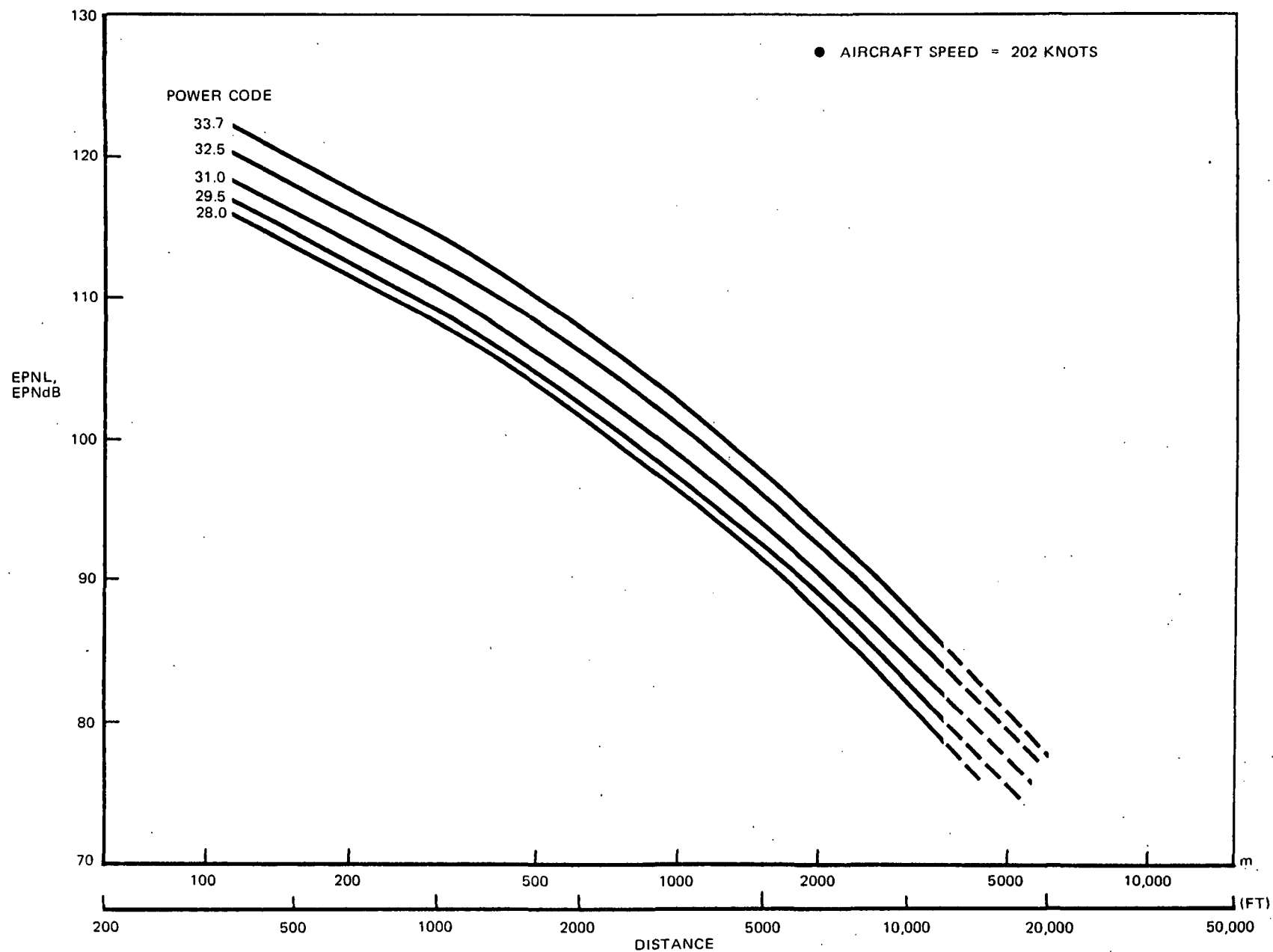


FIGURE 7. PREDICTED EPNL - DISTANCE VARIATIONS - MDC TURBOJET AIRCRAFT - SUPPRESSORS DEPLOYED

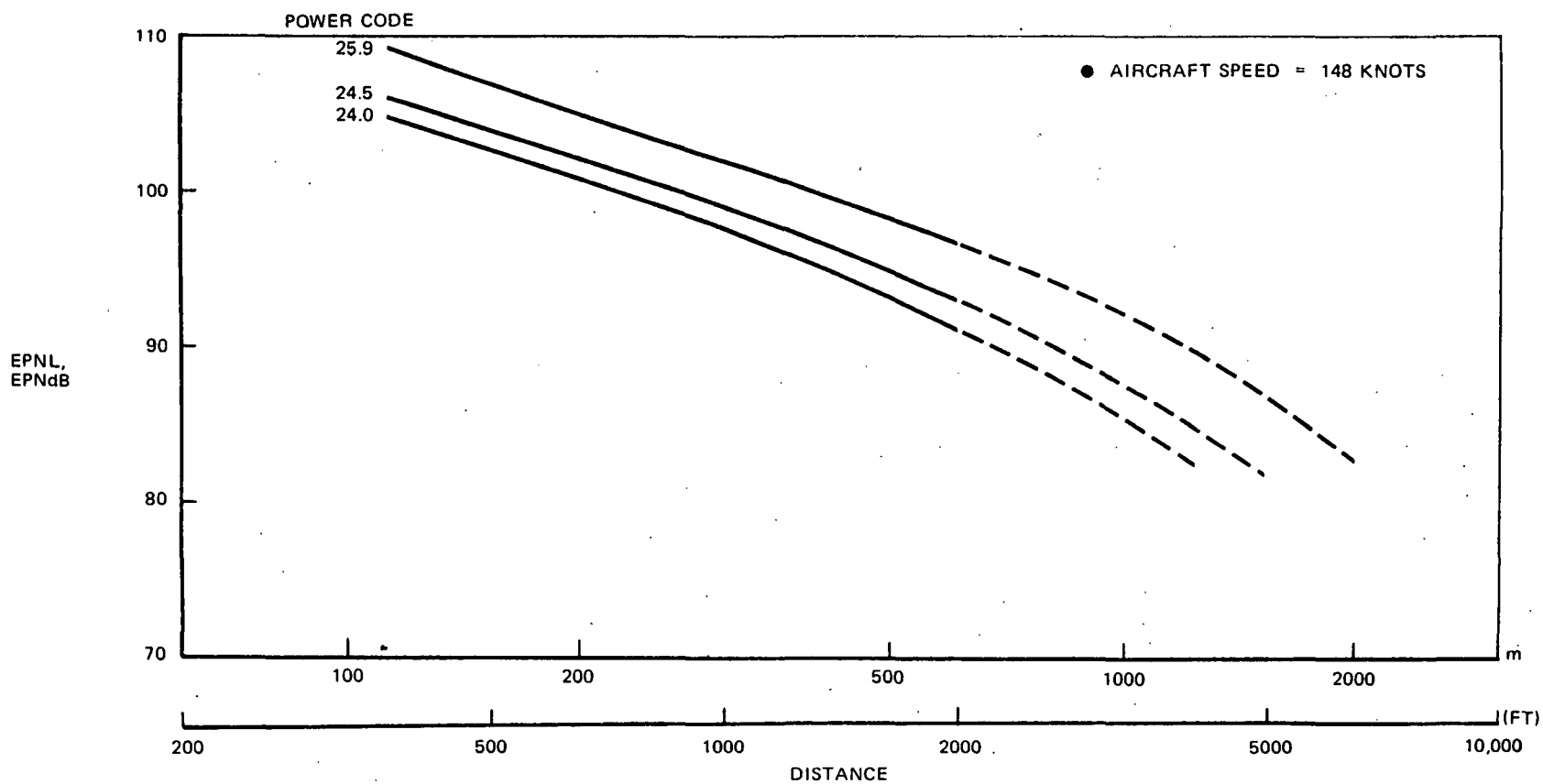


FIGURE 8. PREDICTED EPNL - DISTANCE VARIATIONS - MDC TURBOJET AIRCRAFT -
APPROACH CONDITIONS

noise suppressors deployed. Figure 8 defines the predicted EPNL-distance relationship for approach power settings with the jet noise suppressors stowed.

The exhaust gas temperature with the jet noise suppressors deployed is limited to 1090°K (1500°F) by structural constraints. Thus, the maximum engine thrust attainable at takeoff with the jet noise suppressors is also limited because of the exhaust gas temperature limit and is much less than can be attained with the jet noise suppressors stowed. Therefore, the maximum engine thrust level shown in Figure 6 is higher than that shown in Figure 7.

The associated predicted peak A-weighted sound pressure level variation with distance at several levels of corrected engine thrust is shown in Figures 9 through 11. Figure 9 presents the predicted peak dB(A) - distance relationship for high power settings with the jet noise suppressors stowed. Figure 10 illustrates the predicted peak dB(A) - distance relationship for high power settings with the jet noise suppressors deployed. Figure 11 defines the predicted peak dB(A) - distance relationship for approach power settings with the jet noise suppressors stowed.

6.3.2 VSCE Configuration EPNL and Peak dB(A) Predictions. - The predicted relationship between the EPNL and distance at several levels of corrected engine thrust is shown in Figure 12 for the MDC baseline airplane integrated with P&WA VSCE 502B engines. Again at the low power settings, nonpropulsive noise is included as a noise source. The associated predicted peak dB(A) - distance relationship at several levels of corrected thrust is presented in Figure 13.

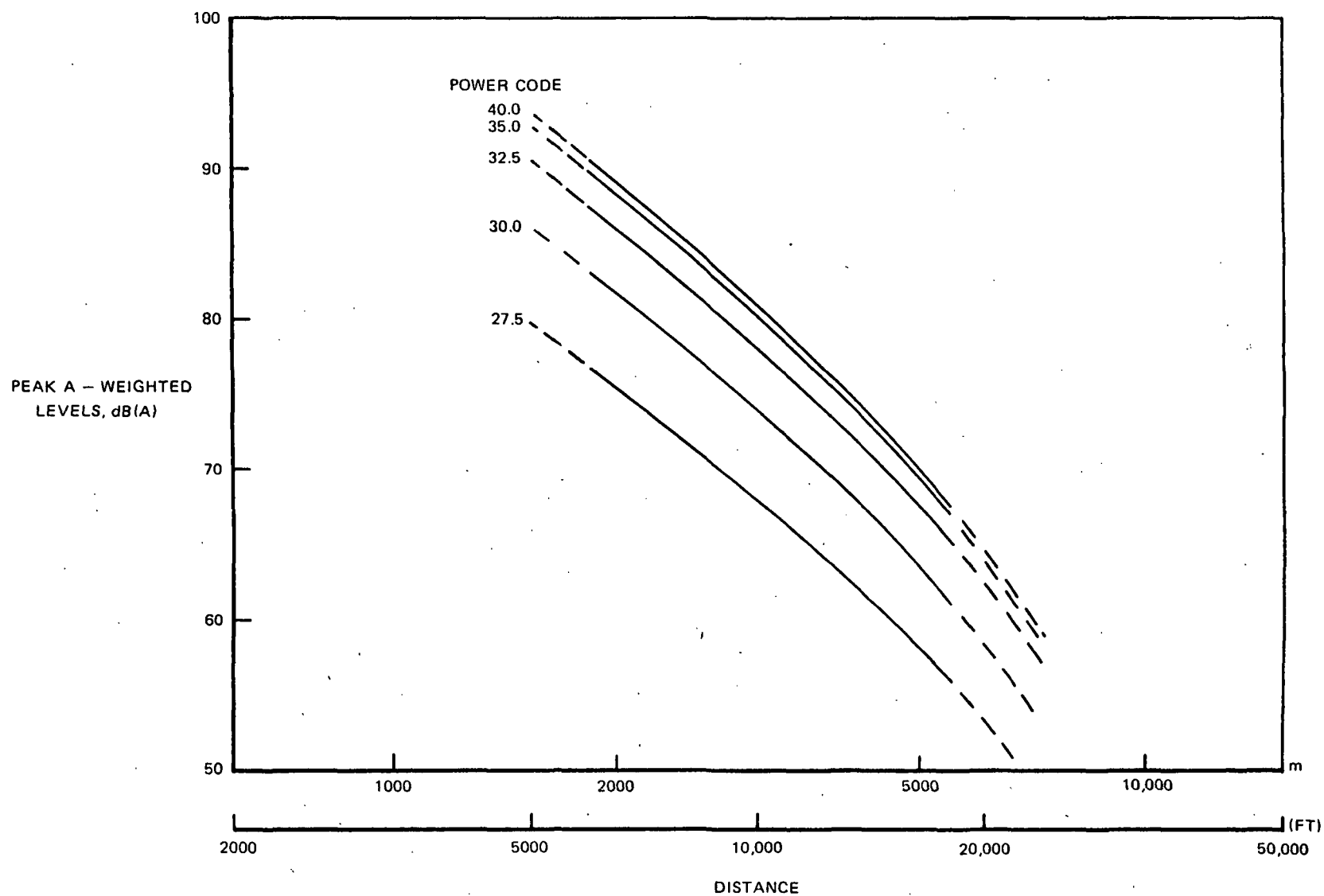


FIGURE 9. PREDICTED PEAK dB(A) - DISTANCE, VARIATIONS - MDC TURBOJET AIRCRAFT - SUPPRESSORS STOWED

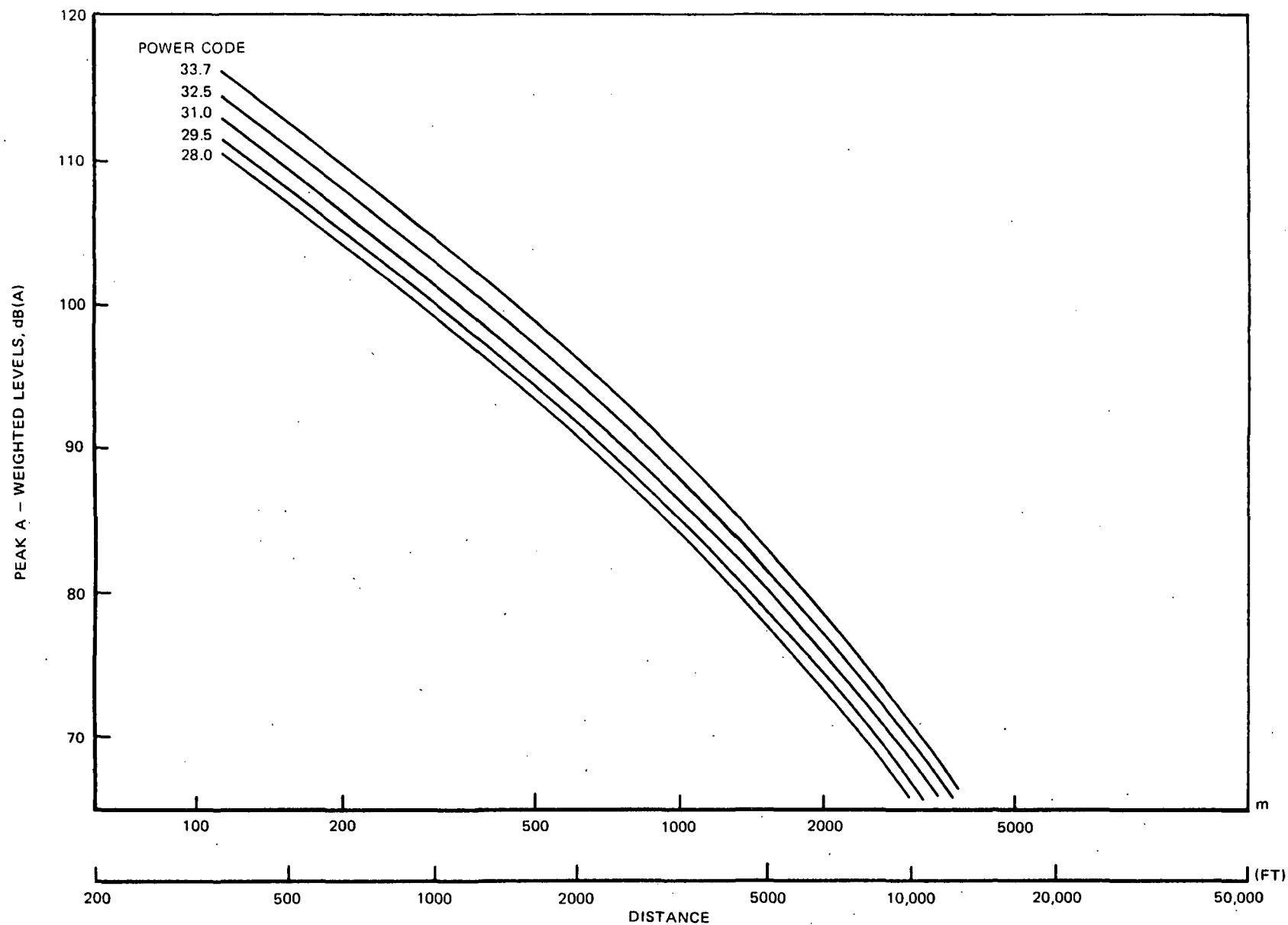


FIGURE 10. PREDICTED PEAK dB(A) - DISTANCE VARIATIONS - MDC TURBOJET AIRCRAFT - SUPPRESSORS DEPLOYED

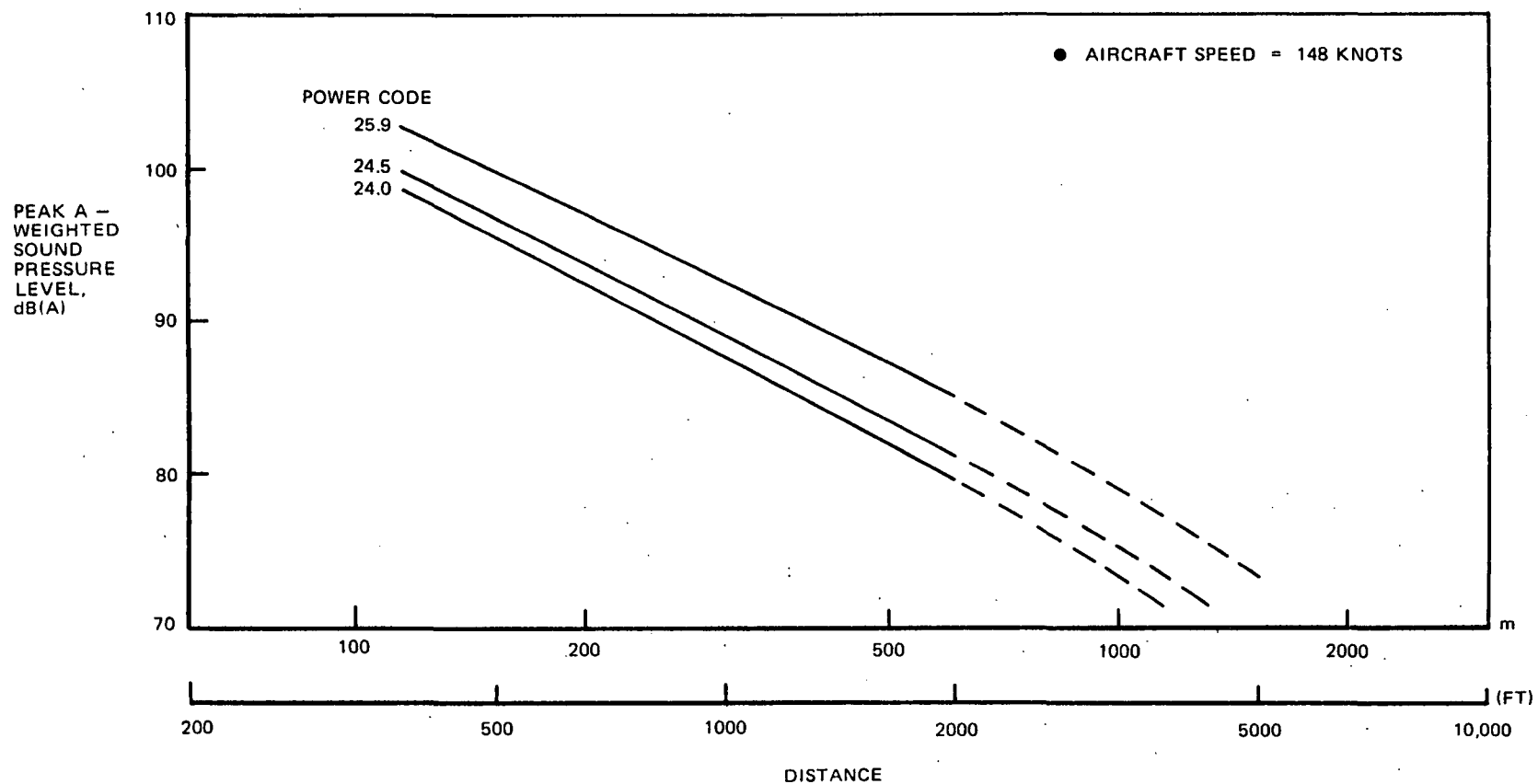


FIGURE 11. PREDICTED PEAK dB(A) - DISTANCE VARIATIONS - MDC TURBOJET AIRCRAFT - APPROACH CONDITIONS

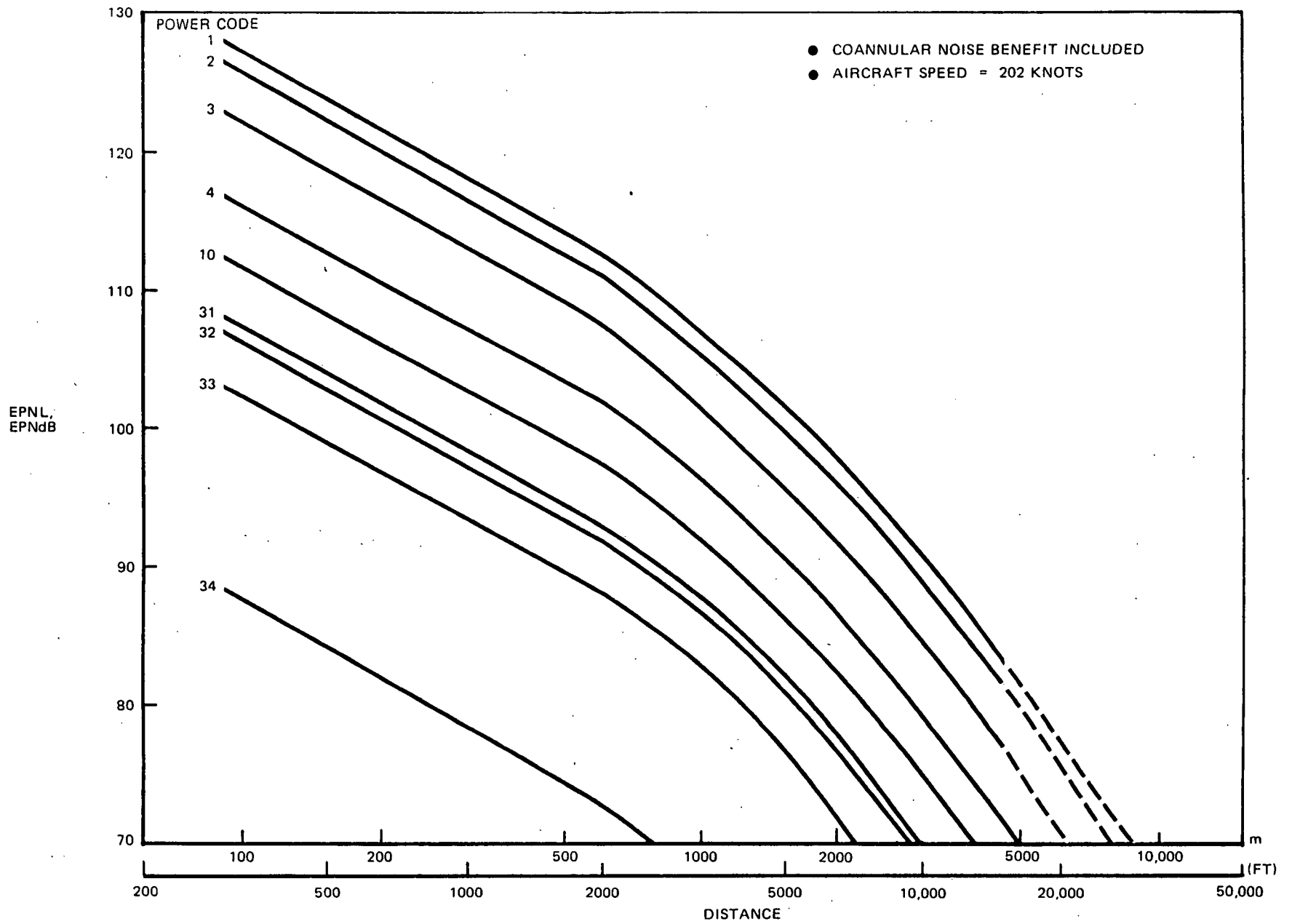


FIGURE 12. PREDICTED EPNL – DISTANCE VSCE 502B CONFIGURATION

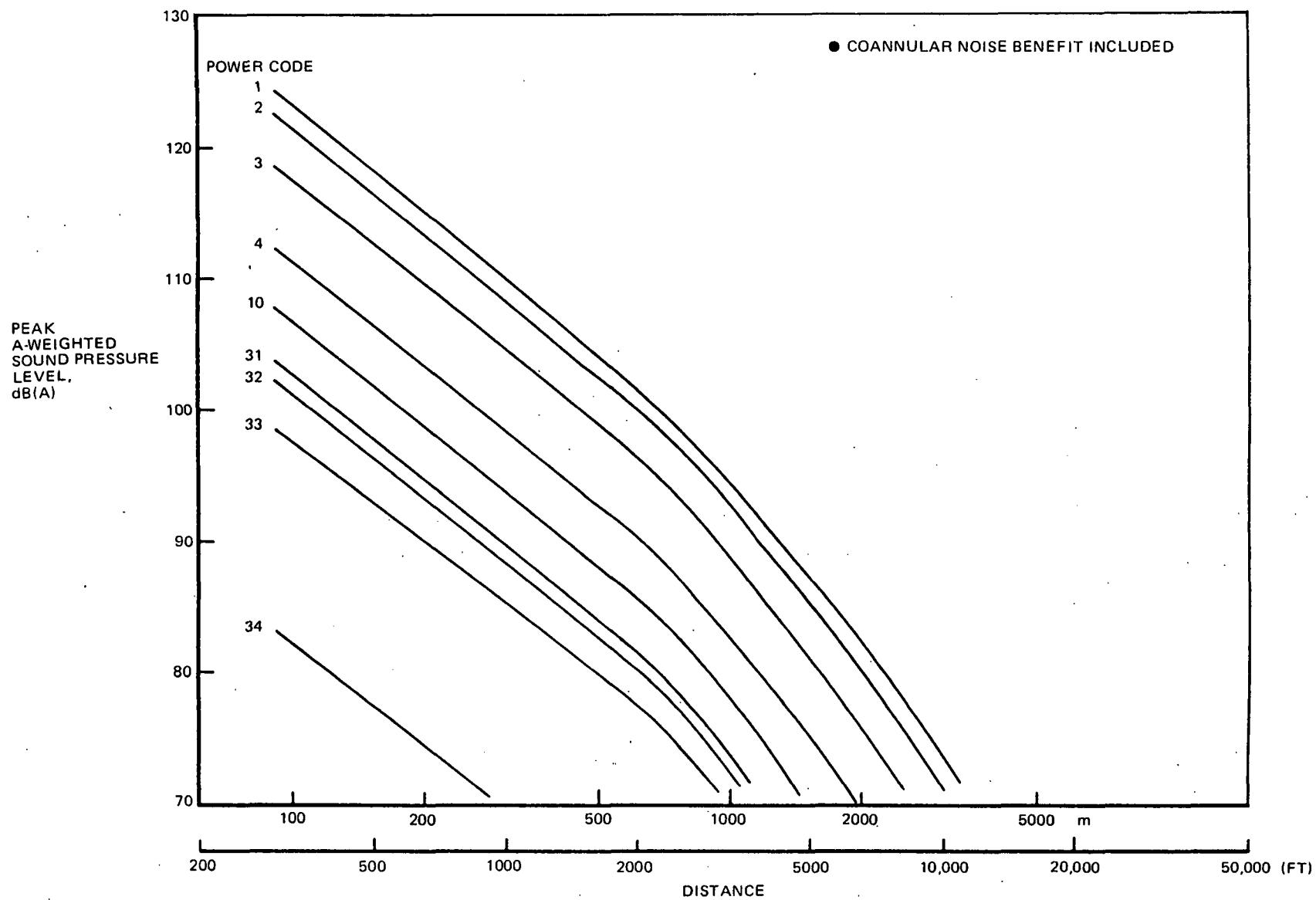


FIGURE 13. PREDICTED PEAK dB(A) – DISTANCE VARIATIONS – VSCE 502B CONFIGURATION

7.0 FLIGHT PATH INVESTIGATION

Several takeoff and approach flight procedures are studied for the two SCAR configurations to determine the influence of these procedures on the predicted noise levels and to identify takeoff and approach procedures which appear promising for noise abatement. The flight procedures for this study are selected by consideration of current practices and alternate procedures to reduce noise. The current FAA practices and location of runway monitors [i.e., takeoff monitor at 6.48 km (3.5 nautical mile) from brake release and landing monitor at 1.85 km (1 nautical mile) from touchdown] have also affected the choice of procedures.

7.1 Takeoff Procedures - SCAR Configurations

The takeoff procedures consist of the following basic steps:

- (a) Accelerate to liftoff and climb to 10.7 meters (35 feet) and V_2 speed - 196.4 KEAS.
- (b) Accelerate at 0.61 m/s^2 (2 fps^2) to $V_2 + 10$ KEAS while retracting gear; speed achieved at $V_2 + 10 = 206$ KEAS.
- (c) Maintain EAS at $V_2 + 10$ KEAS and initiate cutback prior to monitor.
- (d) Maintain thrust for 4 percent climb gradient at $V_2 + 10$ KEAS until noise level is 10 PNdB down from highest level generated at monitor.
- (e) Apply thrust to takeoff power, accelerate at 0.61 m/s^2 (2 fps^2) to 250 KEAS while retracting flaps.
- (f) Continue climb to 5182 m (17,000 feet) at 250 KEAS.

The following procedures are examined:

- (1) Steps (a), (b), (e), and (f) (i.e., no cutback).

- (2) All of the basic steps with cutback initiated at 335 m (1100 feet) altitude and a climb gradient of 4 percent maintained after cutback at a constant EAS of $V_2 + 10$ KEAS until 30,480 m (100,000 feet) downrange of brake release.
- (3) All of the basic steps with cutback initiated at 213 m (700 feet) altitude.
- (4) Same as (3) except cutback is initiated at 335 m (1100 feet) altitude.
- (5) All of the basic steps with cutback initiated 3 seconds prior to monitor and at 1500 m (5000 feet) altitude, accelerate at 0.61 m/s^2 to 360 KEAS while retracting slats and suppressors (if appropriate) and climb at a constant EAS to 5486 m (18,000 feet) altitude.
- (6) All of the basic steps with cutback initiated 3 seconds prior to monitor except a constant EAS of V_2 rather than $V_2 + 10$ KEAS is held past the monitor and cutback is made at 334 m (1100 feet) altitude.
- (7) All of the basic steps with cutback initiated 3 seconds prior to monitor except aircraft is accelerated at 0.61 m/s^2 (2 fps^2) to $V_2 + 37$ KEAS and held rather than $V_2 + 10$ KEAS.

The above stated procedures were selected as representative of current and alternate procedures. Each of the above meets the following FAA takeoff performance requirements for subsonic aircraft up to the obstacle:

$$V_2 \geq 1.125 V_{ZRC}$$

$$V_2 \geq V \text{ for 3 percent climb gradient zero bank angle and 1 engine out}$$

$$V_2 \geq V \text{ for 2 percent climb gradient } 18^\circ \text{ bank angle and 1 engine out}$$

$$V_{LO} \geq 1.05 V_{MU} \text{ 1 engine out}$$

$$V_{LO} \geq 1.10 V_{MU} \text{ all engines out}$$

Some of the procedures studied are in conformance with the requirements of FAR Part 36 for subsonic turbojet airplanes. These procedures illustrate the takeoff and landing flight paths that would be required to meet specified noise level requirements at monitors near an airport boundary.

Alternate procedures such as takeoff without cutback and takeoff with maximum acceleration to 250 KEAS are examined to define the trends on community noise impact. Other potential alternatives which are not investigated in this study are programmed thrust variations and programmed adjustment of flap settings during climb.

The alternative of suppressor retraction with power increase and acceleration to 360 KEAS (for better climb performance) is also examined to determine the attractiveness of such a procedure.

The variations of altitude with distance during takeoff are shown in Figures 14 through 20. Figures 14 through 17 illustrate the takeoff procedures conforming to the FAR Part 36 rules and Figures 18 through 20 are for the non-conforming procedures. Procedure 1, Figure 14, establishes a base for cutback effects as no thrust cutback is included in this procedure. Procedure 2, Figure 15 illustrates the effect of maintaining a 4 percent flight path in a continuing climb beyond the monitor. Procedure 3, Figure 16 represents a procedure using the minimum altitude for cutback permitted by FAR Part 36. Procedure 4, Figure 17 differs from Procedure 5, Figure 16 only in cutback altitude. The cutback altitude in Figure 17 corresponds to the minimum distance prior to the monitor for which a valid measurement of EPNL at cutback power can be obtained.

Procedure 5, Figure 18 is included to illustrate the impact of a normal clean-up and acceleration used to improve climb performance. The effects of an initially lower climb speed and the related higher altitude at the monitor are illustrated by Procedure 6, Figure 19. The effects of higher speed, lower altitude at the monitor and lower thrust required due to a high acceleration are illustrated by Procedure 7, Figure 20.

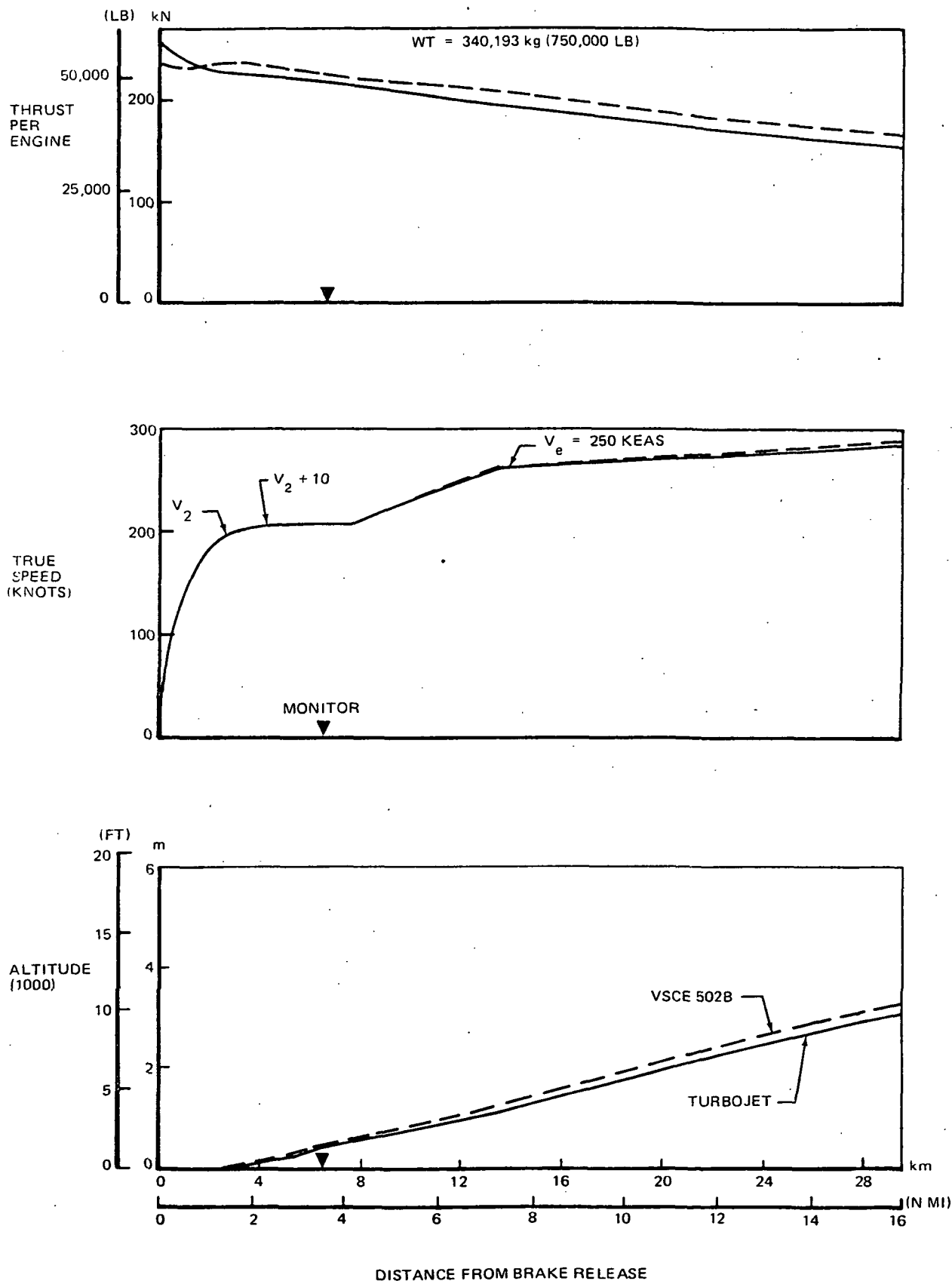


FIGURE 14. SUPERSONIC AIRCRAFT TAKEOFF PROFILES WITHOUT CUTBACK – PROCEDURE 1

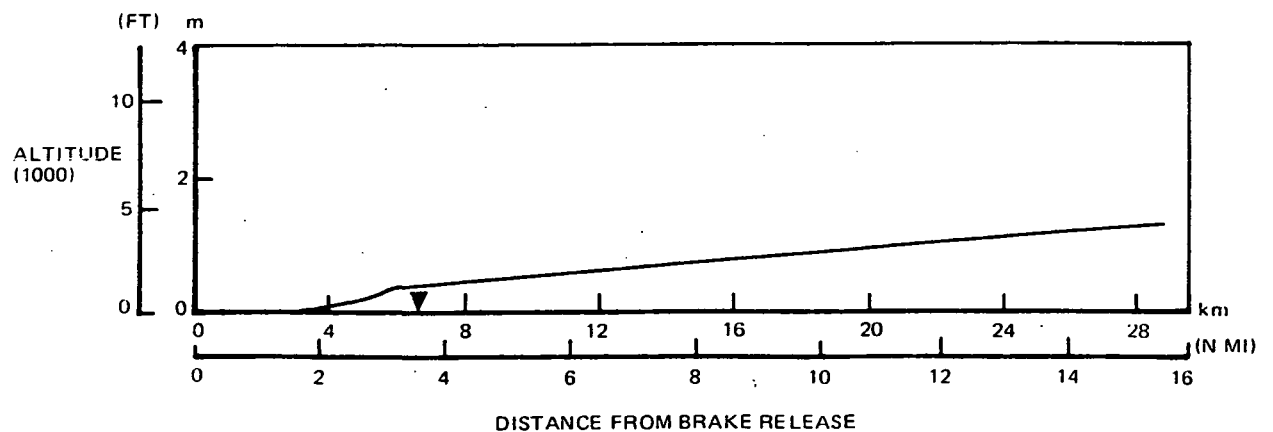
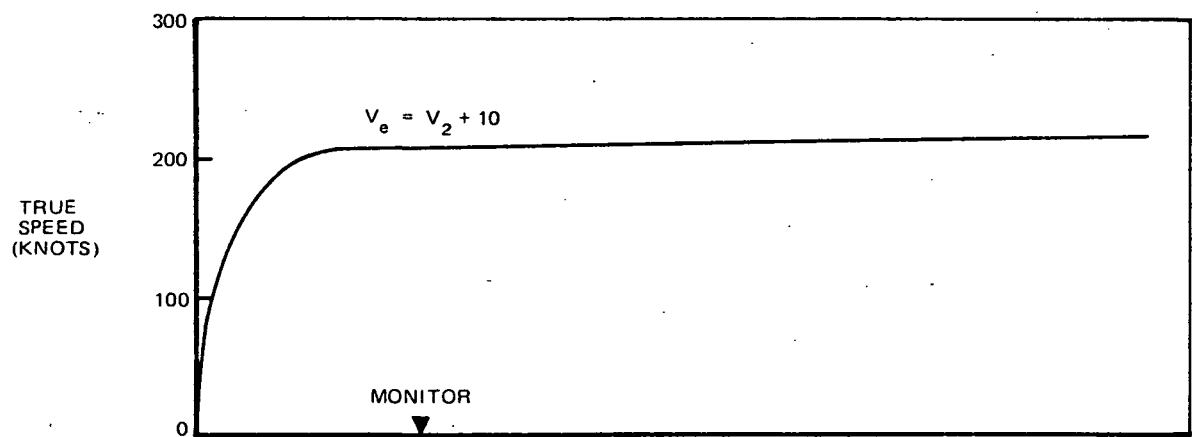
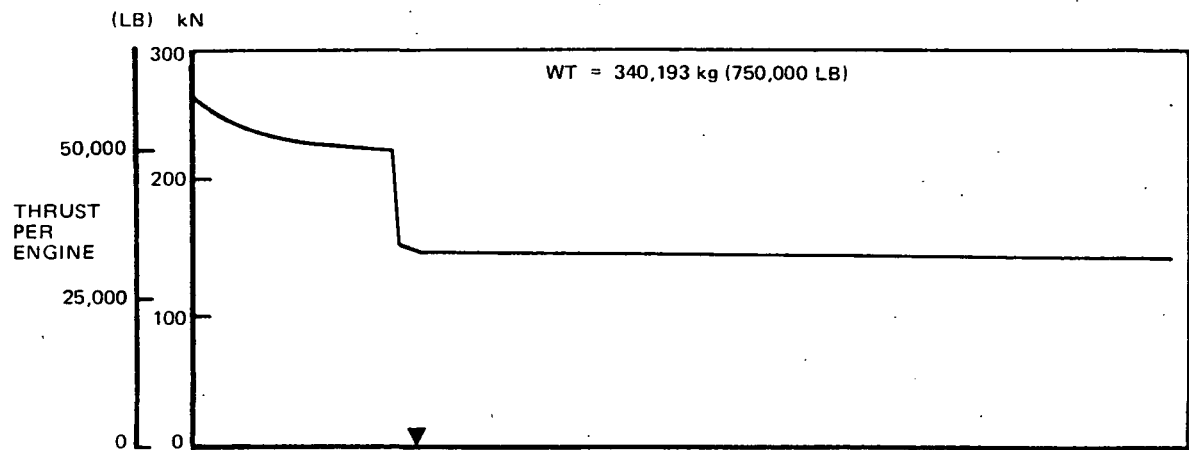


FIGURE 15. MDC TURBOJET AIRCRAFT TAKEOFF PROFILE WITH CUTBACK AT 335m (1100 FT) AND CLIMB AT CUTBACK POWER – PROCEDURE 2

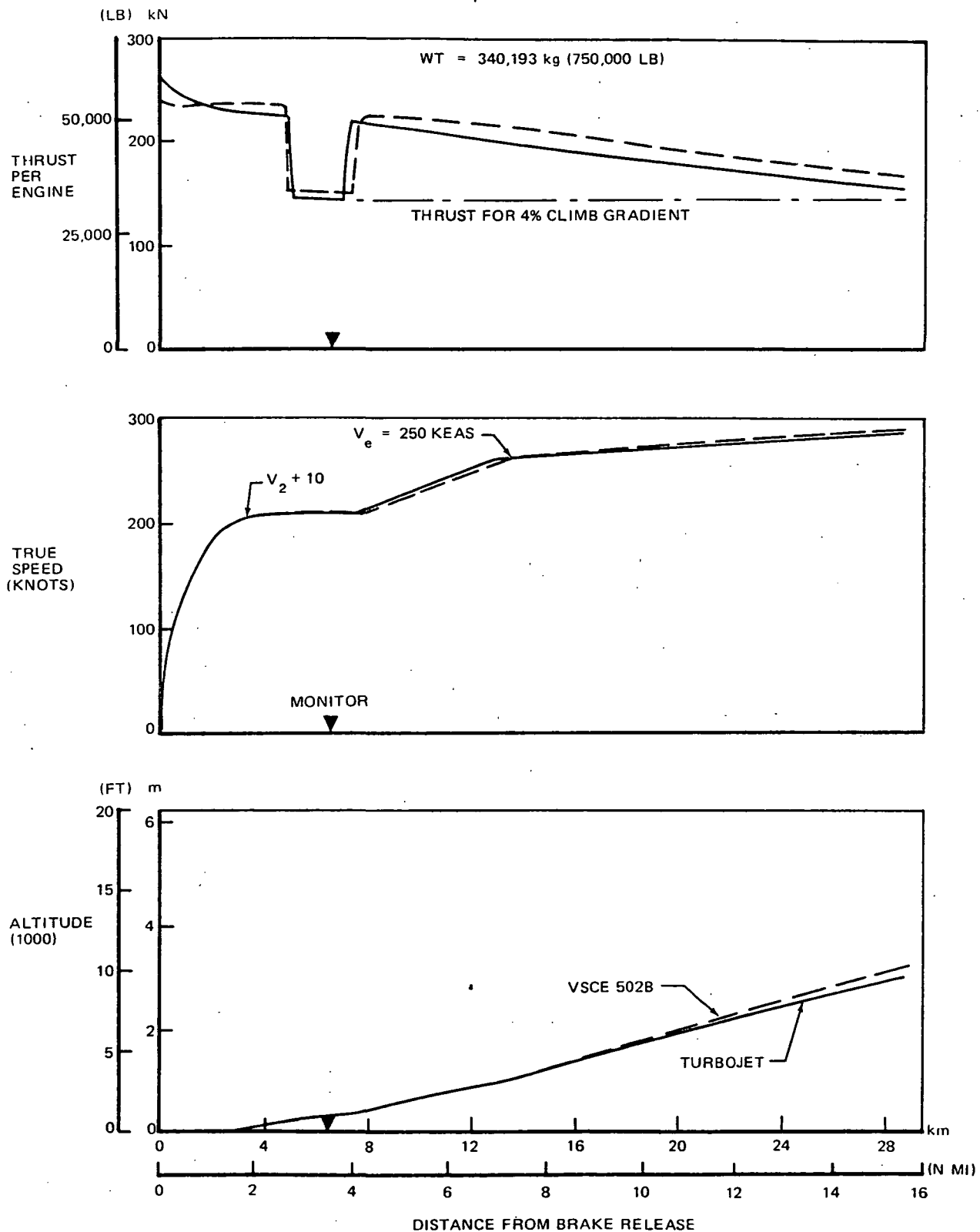


FIGURE 16. SUPERSONIC AIRCRAFT TAKEOFF PROFILES WITH CUTBACK AT 213m (700 FT) – PROCEDURE 3

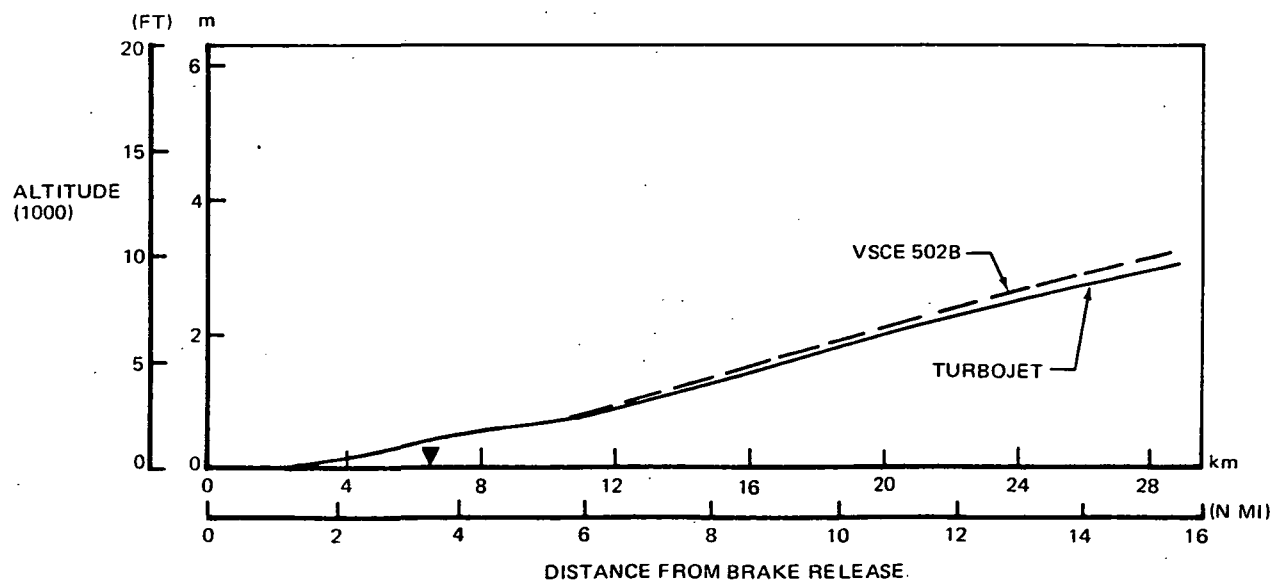
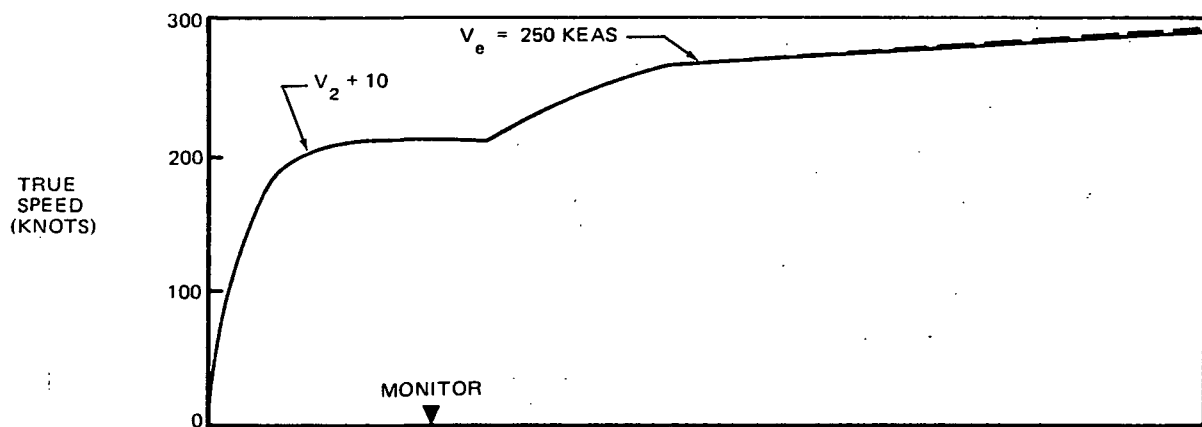
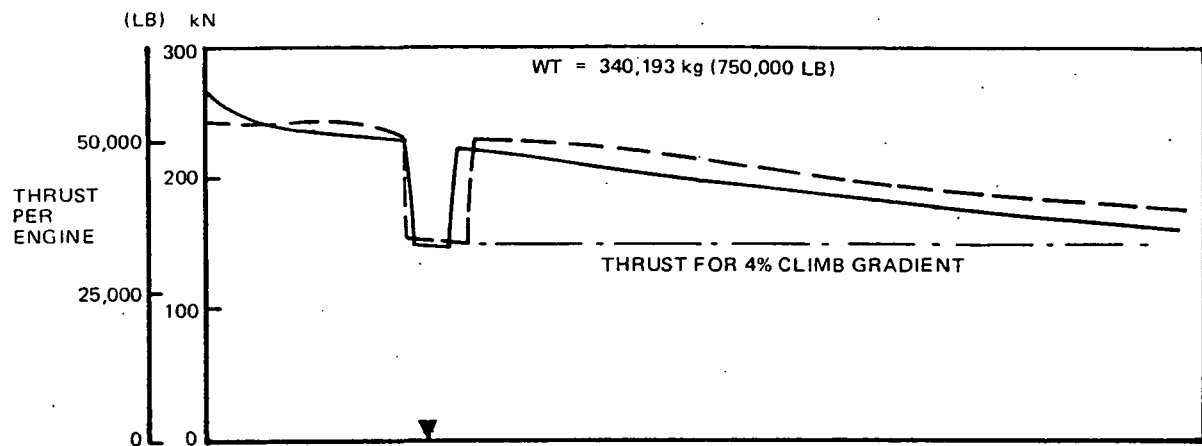


FIGURE 17. SUPERSONIC AIRCRAFT TAKEOFF PROFILES WITH CUTBACK AT 335m (1100 FT) – PROCEDURE 4

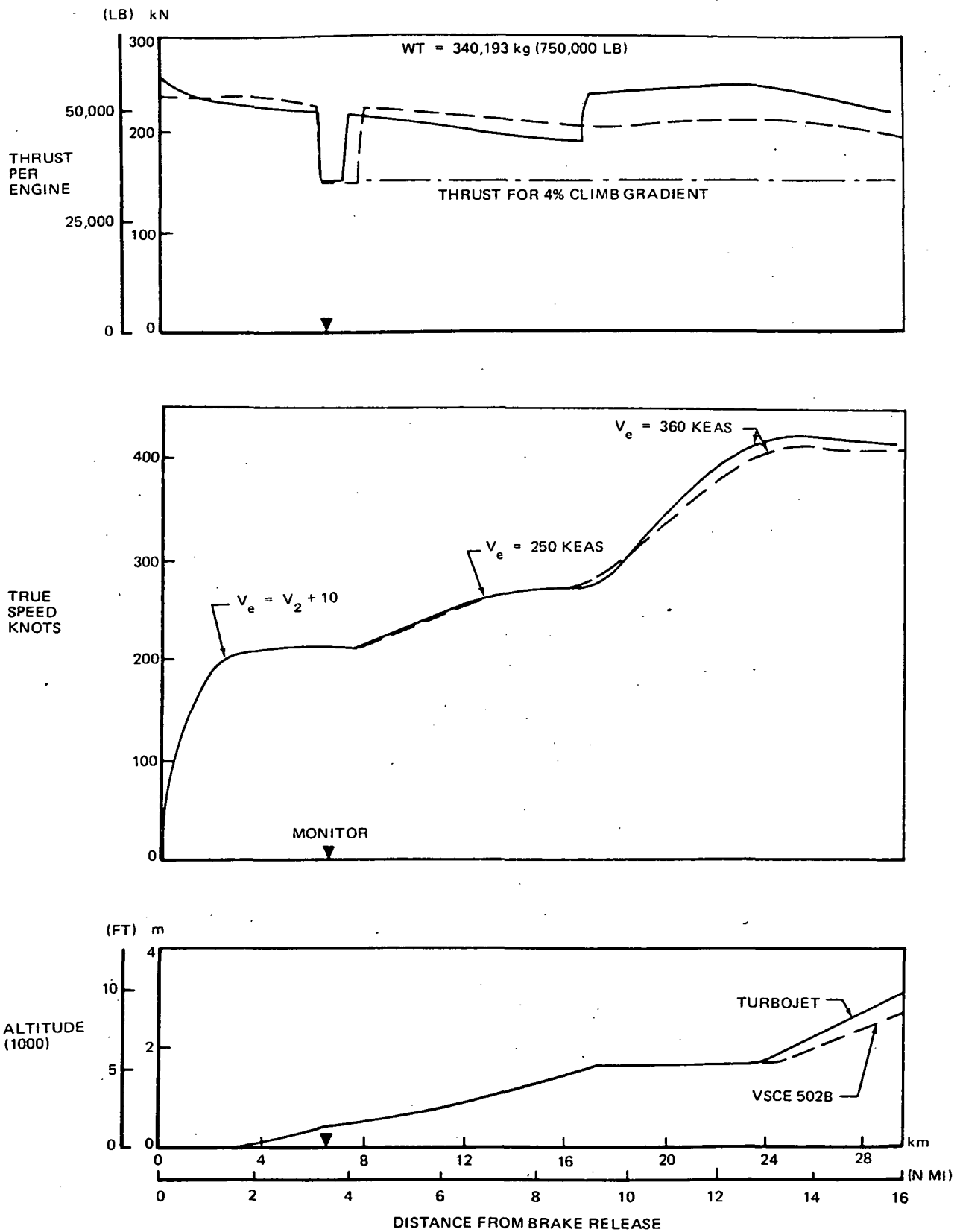


FIGURE 18. SUPERSONIC AIRCRAFT TAKEOFF PROFILES WITH CUTBACK 3 SECONDS PRIOR TO MONITOR AND ACCELERATION AT 1500m (5000 FT) TO 182.5 m/S EAS (300 KEAS) – PROCEDURE 5

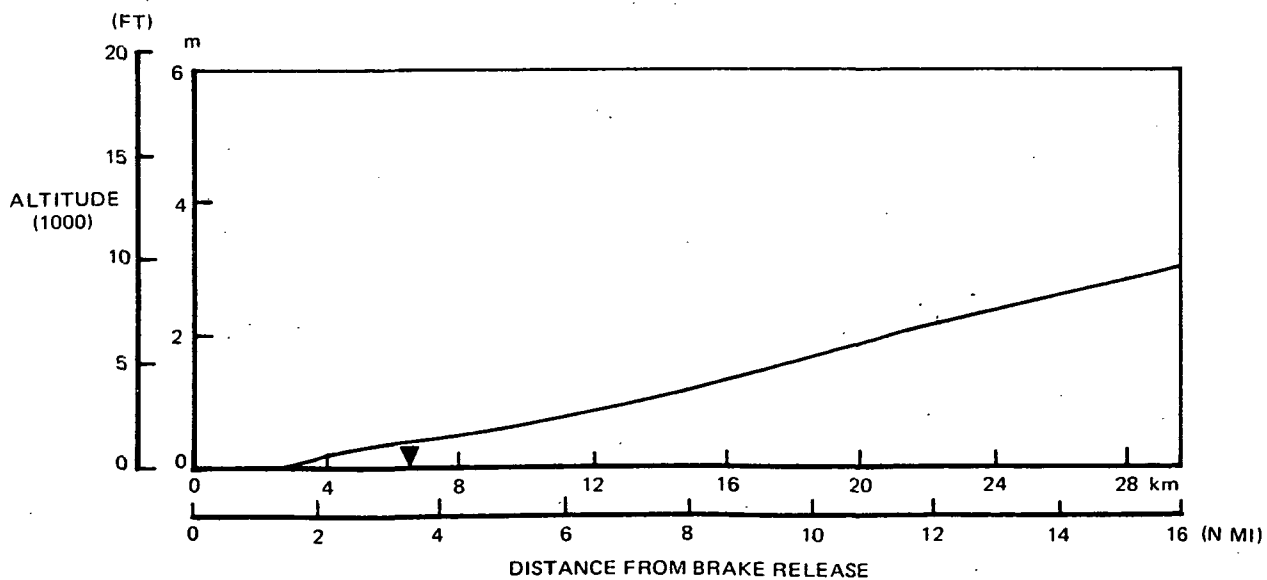
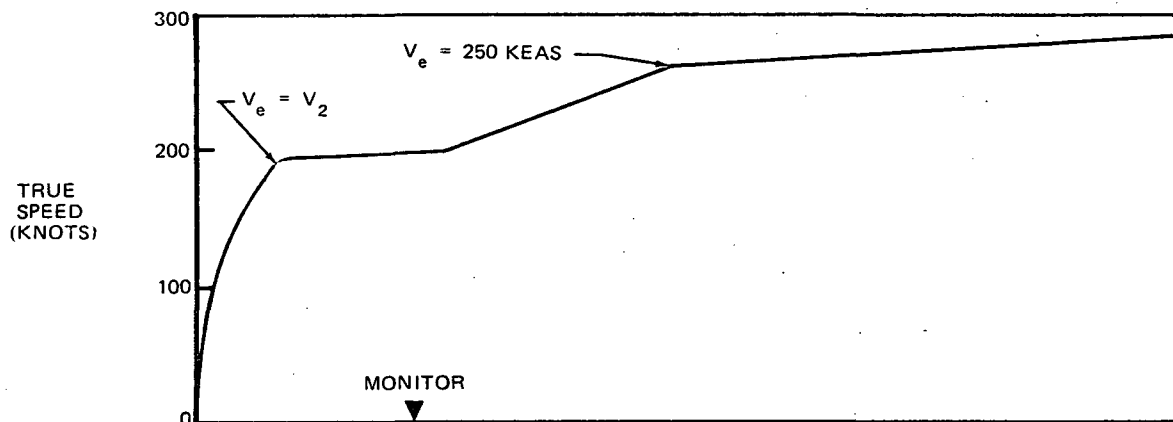
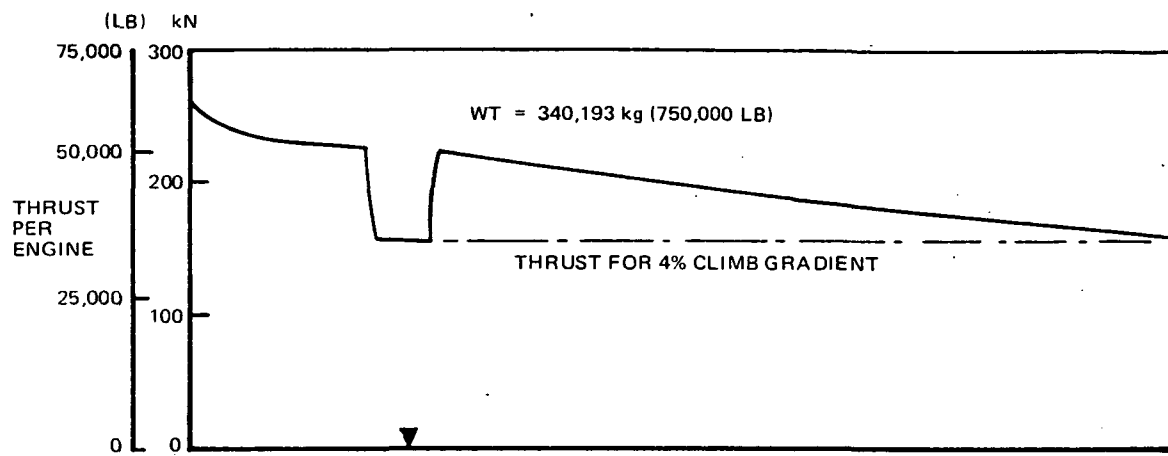


FIGURE 19. MDC TURBOJET AIRCRAFT TAKEOFF PROFILE WITH CUTBACK AT 335m (1100 FT) AND AIRSPEED HELD AT V_2 – PROCEDURE 6

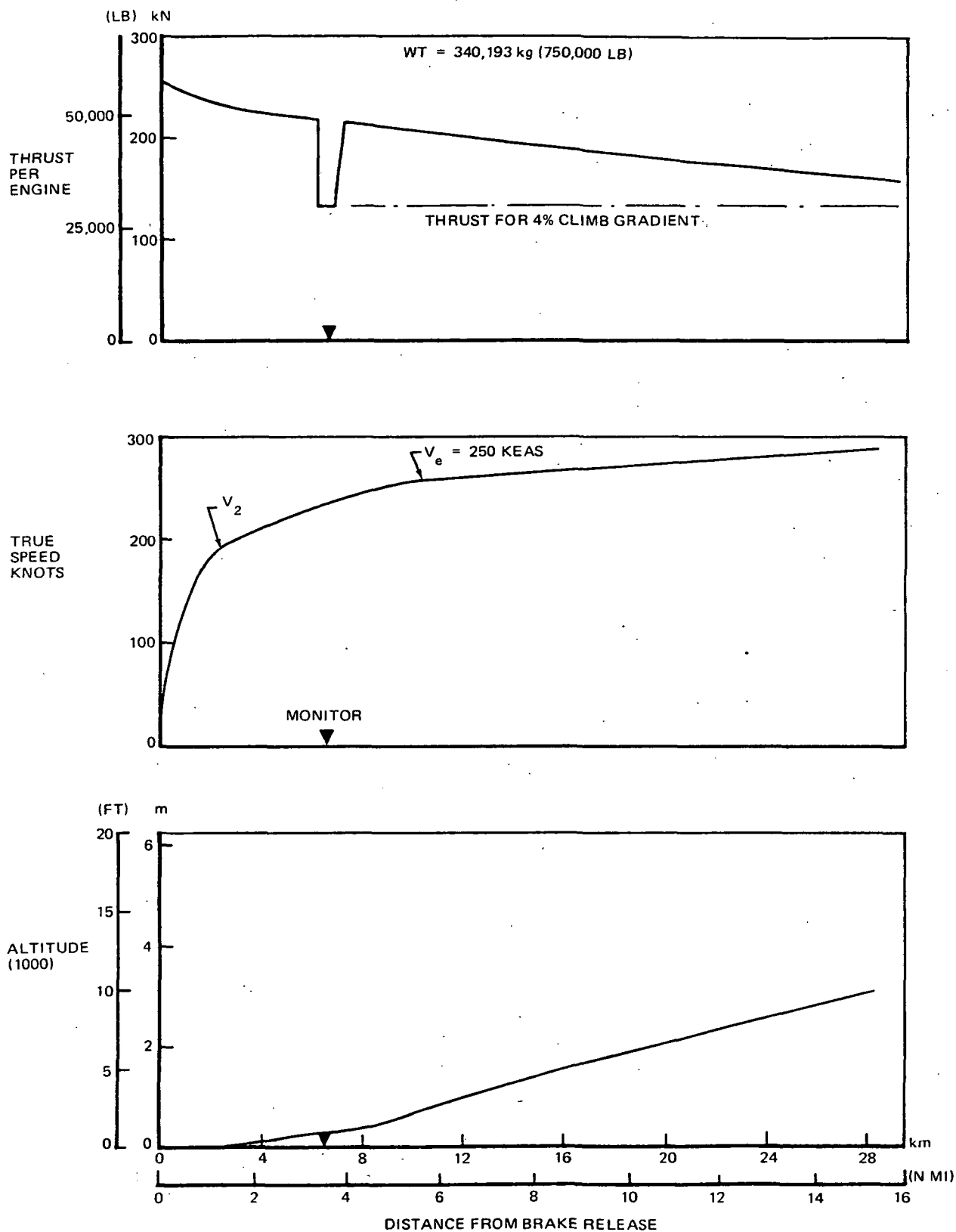


FIGURE 20. MDC TURBOJET AIRCRAFT TAKEOFF PROFILE WITH MAXIMUM ACCELERATION AFTER LIFTOFF AND CUTBACK 3 SECONDS PRIOR TO MONITOR – PROCEDURE 7

Table 2 presents a comparison of thrust and altitude conditions at the monitor resulting from each of the procedures.

For a given aircraft speed, the highest altitude over a monitor near the airport is achieved by the full power takeoff procedure. Any type of cutback lowers the altitude over the monitor and at all subsequent distances from brake release. Reducing the aircraft speed to V_2 , for example, increases the altitude over the monitor, but requires an increased thrust at cutback to meet the 4 percent climb gradient. Beyond the monitor, the rate of climb is less because of the reduced speed, and the altitude attained will be lower at distances away from the airport. Increasing the aircraft speed above $V_2 + 10$ KEAS, on the other hand, results in a lower altitude over the monitor near the airport, but the rate of climb is better and the altitudes attained at distances away from the airport are higher.

7.2 Approach Flight Paths - SCAR Configurations

The approach procedures examined are as follows:

1. Approach from 914 m (3000 feet) altitude along a 3° glideslope at a constant approach speed of 140 KEAS.
2. Same as (1) except that a 6° glideslope is flown to 305 m (1000 feet) altitude where a transition to a 3° glideslope is made.
3. Approach from 914 m (3000 feet) altitude at a 3° glideslope at constant deceleration from 20 KEAS above the 140 KEAS approach speed to the approach speed at touchdown. This corresponds to an approximate deceleration of 0.097 KT/sec.

Table 3 presents a comparison of the thrust level conditions at the monitor that result from each of these procedures.

TABLE 2
SUMMARY OF ALTITUDE AND RELATIVE THRUST LEVELS AT THE FAR PART 36
TAKEOFF MEASURING POINT FOR THE STUDY TAKEOFF FLIGHT PATHS

PROCEDURE	TURBOJET		VSCE 502BD	
	HEIGHT AT MONITOR METERS (FEET)	THRUST AT MONITOR % OF TAKEOFF THRUST	HEIGHT AT MONITOR METERS (FEET)	THRUST AT MONITOR % OF TAKEOFF THRUST
1	429 (1408)	100	453 (1487)	100
2	396 (1300)	66.3	----	--
3	313 (1027)	66	331 (1086)	66.9
4	396 (1300)	66.3	407 (1334)	66.3
5	422 (1383)	68.9	446 (1463)	65.9
6	412 (1353)	70.9	----	--
7	292 (958)	62.2	----	--

TABLE 3

SUMMARY OF RELATIVE THRUST LEVELS AT THE FAR PART 36 APPROACH
MEASURING STATION FOR THE STUDY APPROACH FLIGHT PATHS

PROCEDURE	THRUST AT MONITOR ON GLIDESLOPES - % OF PROCEDURE 1	
	TURBOJET	VSCE 502BD
1	100	100
2	93.9	94.0
3	88.9	89.5

7.3 DC-8-61 Flight Paths

The takeoff flight paths for the DC-8-61 aircraft considered in this study followed an ATA recommended procedure which consists of three segments as follows:

- I. First Segment - Takeoff to 457 m (1500 ft)
 1. Takeoff power
 2. $V_2 + 10$ KEAS
 3. Takeoff flaps
- II. Second Segment - from 457 m (1500 ft) to 914 m (3000 ft)
 1. $V_2 + 10$ KEAS
 2. Optimum flap setting speed permitting*
 3. Reduce to not less than climb power

* Retract or retain flap setting as required
- III. Third Segment - At 914 m (3000 ft)
 1. Retract flaps on schedule
 2. Normal en route climb

The resulting flight paths for the DC-8-61 aircraft operating at maximum takeoff gross weight and at typical gross weight for a typical mission [1850 kilometers (1000 n.mi.) at a 60 percent load factor] are shown in Figure 21.

The standard approach glideslope after intercept of the instrument landing system at 914 m (3000 ft) is employed for the DC-8-61 aircraft studied.

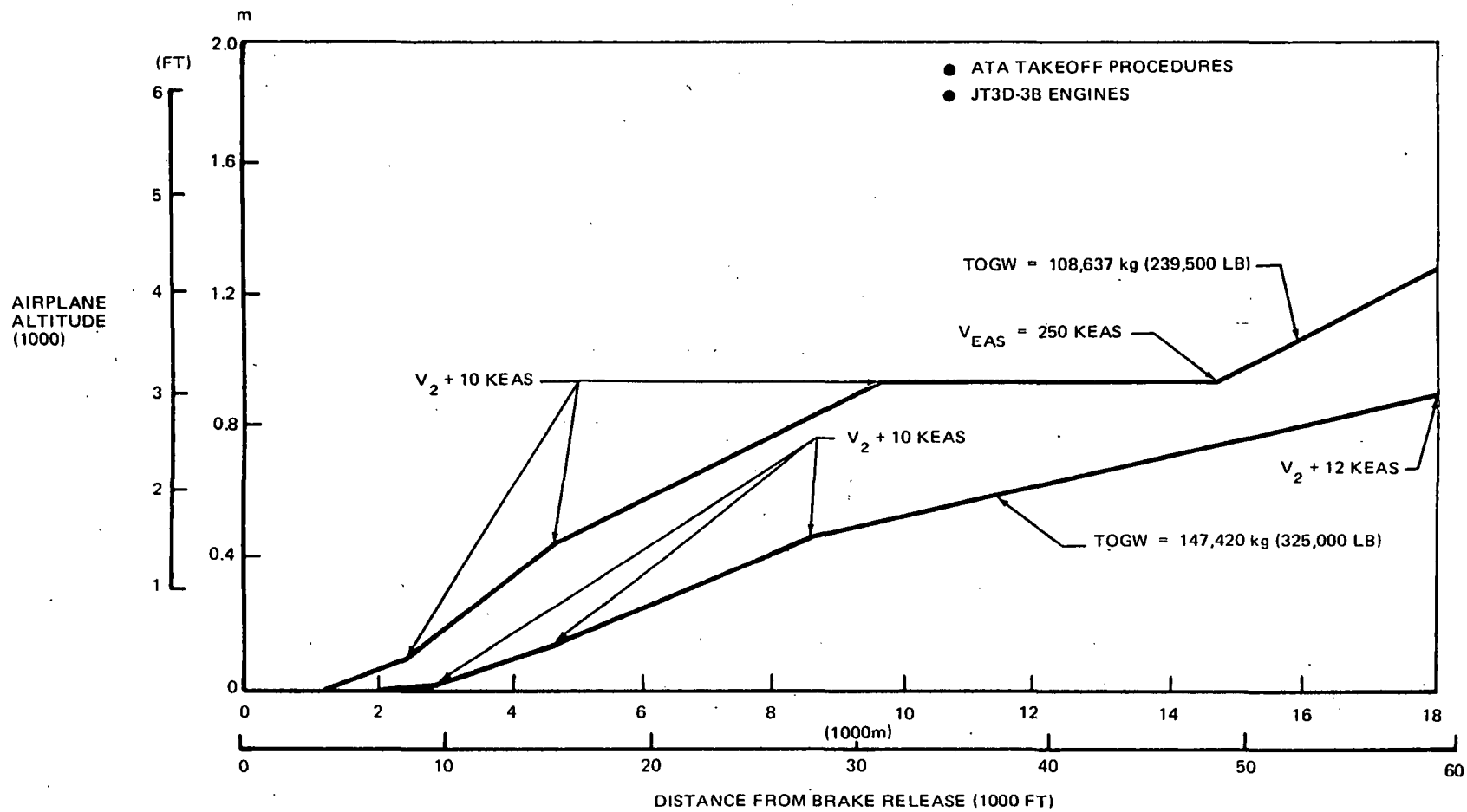


FIGURE 21. DC-8-61 AIRCRAFT TAKEOFF FLIGHT PATHS

8.0 COMMUNITY NOISE LEVELS AND CONTOURS

The aircraft flight paths defined in Section 7 and the EPNL-distance and dB(A)-distance relationships established in Section 6 have been used to estimate noise levels. Seven different takeoff flight paths have been investigated for the MDC turbojet aircraft, four takeoff paths for the VSCE 502B configuration, and two takeoff paths for the DC-8-61 aircraft; one at maximum gross weight and the other at a typical mission weight. Three approach profiles are included for each of the two supersonic aircraft and one profile for the DC-8-61. Noise levels have been estimated for all flight paths at the FAR Part 36 locations. In addition, centerline noise levels directly under the flight path have been determined for each flight path. With the centerline noise levels as a guide, the noise levels for community noise contours have been determined and the contours calculated.

8.1 Noise Level Estimates at FAR Part 36 Locations

The FAR Part 36 noise level estimates for the DC-8-61 aircraft and for the two SCAR configurations are presented in Tables 4 and 5. All supersonic aircraft estimated noise levels are for the maximum takeoff gross weights and therefore, represent the highest noise levels to be expected.

8.1.1 Sideline - It can be observed from Table 4 that all takeoff flight procedures for the MDC turbojet aircraft produce sideline noise levels meeting the current FAR Part 36 noise level requirement of 108 EPNdB. Table 5 shows that the VSCE 502B engine powered configuration also meets the current sideline requirement. However, the VSCE 502B configuration sideline levels are 4 dB higher than the MDC turbojet aircraft. The DC-8-61 sideline noise levels are lower than the FAR Part 36 requirement and lower than either of the supersonic aircraft.

8.1.2 Takeoff (Cutback) - Table 4 shows that only one of the four takeoff procedures for the MDC turbojet aircraft produces noise levels below the FAR Part 36 noise level requirement of 108 EPNdB. The takeoff cutback at 395 m (1300 ft) altitude is not in conformance with FAR Part 36 rules. The best takeoff procedure to use to meet the requirement is a full power takeoff

TABLE 4
ESTIMATED NOISE LEVELS - FAR PART 36 LOCATIONS
DC-8-61 vs MDC TURBOJET

DC-8-61/JT3D-3B

<u>TAKEOFF GROSS WEIGHT</u>	<u>LANDING GROSS WEIGHT</u>	<u>SIDELINE</u>		<u>TAKEOFF CUTBACK</u>		<u>APPROACH</u>	
		<u>EPNdB</u>	<u>dBA</u>	<u>EPNdB</u>	<u>dBA</u>	<u>EPNdB</u>	<u>dBA</u>
147,147 kg (325,000 LB)	108,862 kg (240,000 LB)	101	90	110	99	115	103
FAR PART 36 Requirement		106.2		103.6		106.2	
108,635 kg (239,500 LB)*	96,674 kg (213,130 LB)	102	91	96	83	113	102

MDC TURBOJET CONFIGURATION (Maximum Takeoff and Landing Gross Weights)

TAKEOFF** - FULL POWER	104	91	112	101		
TAKEOFF** - CUTBACK 213 m (700 FT)	103	90	110	101		
TAKEOFF** - CUTBACK 335 m (1100 FT)	104	91	107	98		
TAKEOFF** - CUTBACK 395 m (1300 FT)***	104	91	107	97		
APPROACH - .052 rad (3°)					108	101
APPROACH - 2-SEGMENT, .104 rad + .052 rad (6° + 3°)					107	101
APPROACH - DECELERATING - 10.3 m/s DURING APPROACH					107	100
FAR PART 36 Requirement	108.0		108.0		108.0	

*TYPICAL MISSION GROSS WT. USING ATA CUTBACK PROC. [CLIMB THRUST AT 457 m (1500 FT); CLEAN UP AT 914 m (3000 FT)]

**ALL TAKEOFFS WITH JET NOISE SUPPRESSORS DEPLOYED

***CUTBACK PROCEDURE NOT IN CONFORMANCE WITH FAR PART 36 RULES, ENGINES NOT SPOOLED DOWN AND STABILIZED PRIOR TO MONITOR

NOTE: SIDELINE MONITOR IS AT 0.35 NAUTICAL MILE

TABLE 5
ESTIMATED NOISE LEVELS - FAR PART 36 LOCATIONS
DC-8-61 vs VSCE 502BD

DC-8-61/JT3D-3B

<u>TAKEOFF GROSS WEIGHT</u>	<u>LANDING GROSS WEIGHT</u>	<u>SIDELINE</u>		<u>TAKEOFF CUTBACK</u>		<u>APPROACH</u>	
		<u>EPNdB</u>	<u>dBA</u>	<u>EPNdB</u>	<u>dBA</u>	<u>EPNdB</u>	<u>dBA</u>
147,147 kg (325,000 LB)	108,862 kg (240,000 LB)	101	90	110	99	115	103
FAR PART 36 Requirement		106.2		103.6		106.2	
108,635 kg (239,500 LB)*	96,674 kg (213,130 LB)	102	91	96	83	113	102

VSCE502BD ENGINE POWERED CONFIGURATION (Maximum Takeoff and Landing Gross Weights)

TAKEOFF - FULL POWER	108	97	114	105		
TAKEOFF - CUTBACK 213 m (700 FT)	107	96	107	98		
TAKEOFF - CUTBACK 335 m (1100 FT)	108	97	105	95		
TAKEOFF - CUTBACK 395 m (1300 FT)**	108	97	104	94		
APPROACH - .052 rad (3°)					107	100
APPROACH - 2-SEGMENT, .104 rad + .052 rad (6° + 3°)					106	100
APPROACH - DECELERATING - 10.3 m/s DURING APPROACH					106	99
FAR PART 36 Requirement	108.0		108.0		108.0	

*TYPICAL MISSION GROSS WT. USING ATA CUTBACK PROC. [CLIMB THRUST AT 457 m (1500 FT); CLEAN UP AT 914 m (3000 FT)]

**CUTBACK PROCEDURE NOT IN CONFORMANCE WITH FAR PART 36 RULES, ENGINES NOT SPOOLED DOWN AND STABILIZED PRIOR TO MONITOR

NOTE: SIDELINE MONITOR IS AT 0.35 NAUTICAL MILE

with cutback initiated at 335 m (1100 ft) altitude to a thrust producing a 4 percent climb gradient.

For the VSCE 502B configuration (Table 5), two of the takeoff cutback procedures produce noise levels that meet the current FAR Part 36 requirements. The cutback initiated at the higher altitude [335 m, (1100 ft)] is preferred because of its lower net noise level. The cutback procedure at an altitude of 395 m (1300 ft) is not in conformance with the FAR Part 36 rules.

The takeoff cutback noise levels for both supersonic aircraft are lower than the DC-8-61 maximum takeoff gross weight noise levels, but higher than the typical mission DC-8-61 takeoff-cutback noise levels.

8.1.3 Approach - Tables 4 and 5 show that all three approaches studied for the MDC turbojet aircraft and the VSCE aircraft meet the current FAR Part 36 noise level requirement of 108 EPNdB. The tables show that the VSCE 502B configuration noise levels are 1 EPNdB lower than the MDC turbojet levels. The approach noise levels for both supersonic aircraft are lower than either the maximum approach weight or typical mission weight DC-8-61 airplanes.

8.2 Runway Centerline Noise Level Variations with Distance

Takeoff and approach centerline noise levels have been determined for the two supersonic cruise aircraft configurations. Centerline noise level variations during takeoff have been calculated for the DC-8-61 aircraft also. The results are shown in Figures 22 and 23 for the MDC turbojet airplane during takeoff and approach, respectively, and in Figures 24 and 25 for the VSCE 502B configuration during takeoff and approach, respectively. Figure 26 illustrates the noise levels for the DC-8-61 aircraft during takeoff.

8.2.1 MDC Turbojet Aircraft - The centerline noise plots (Figure 22) have been examined to determine the takeoff flight path that would produce the lowest community noise levels for the MDC baseline configuration. As shown in Figure 22, the flight path with the suppressor deployed to the maximum

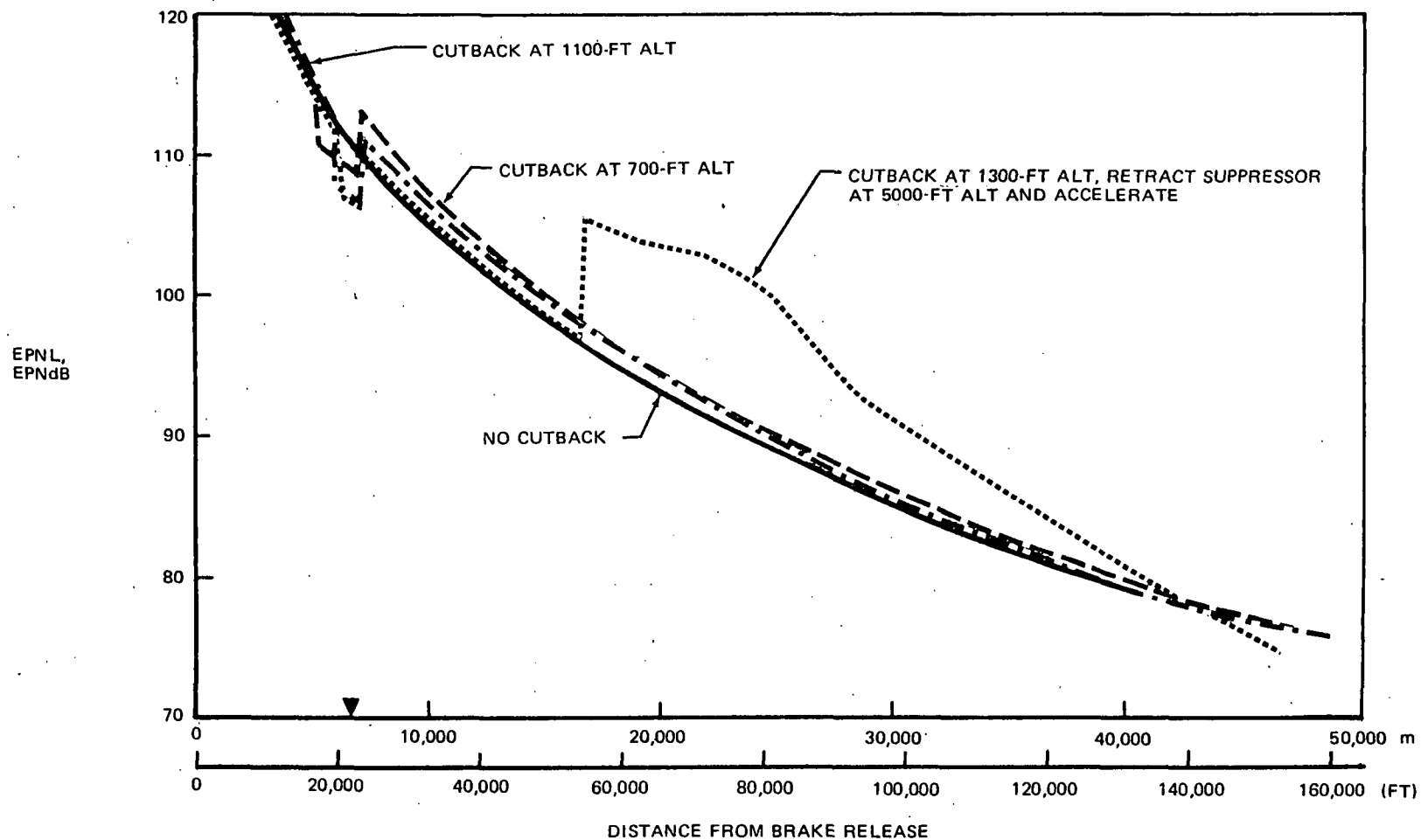


FIGURE 22. ESTIMATED TAKEOFF CENTERLINE NOISE LEVELS – MDC TURBOJET AIRCRAFT

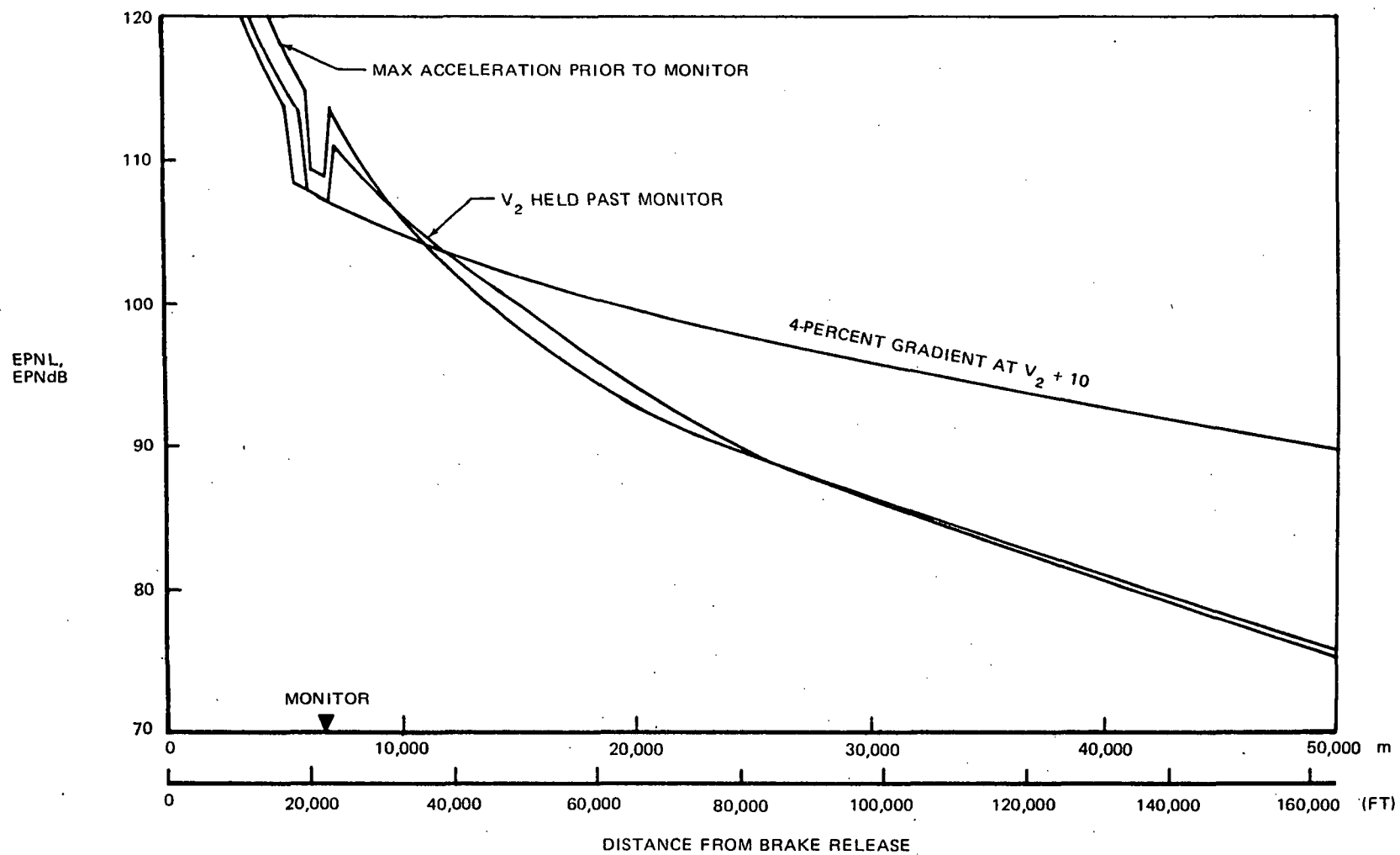


FIGURE 22. (CONTINUED) ESTIMATED TAKEOFF CENTERLINE NOISE LEVELS – MDC TURBOJET AIRCRAFT

allowable altitude of 3658 m (12,000 ft) and without power cutback permits the aircraft to reach a noise level of 90 EPNdB in the minimum distance from brake release. However, the noise level at a monitor 6.48 kilometers (3.5 nautical miles) from brake release would exceed 108 EPNdB.

The two flight paths with cutback at altitudes of 213 m (700 ft) or 335 m (1100 ft) permit the aircraft to meet the current FAR Part 36 requirements. However, takeoff power must be reapplied shortly after passing the monitor to produce lower noise levels at greater distances from brake release (Figure 22). If the suppressor is retracted at an altitude below the maximum allowable, it can be observed from Figure 22 that the noise levels are significantly higher due to retraction of the suppressor and an increase in power setting from maximum suppressed to maximum climb. Therefore, the increased climb gradient does not compensate for increased source noise until large distances from brake release.

Figure 23 shows that, for the MDC turbojet airplane, the two segment approach produces the lowest noise levels at distances greater than 5000 m (16,404 ft) from the runway threshold. The noise increase at about 4500 m is caused by a transient thrust increase to maintain the 3 degree glideslope at the transition from the 6 degree to the 3 degree glideslope. More precise management of engine thrust would reduce the magnitude of this transient. The decelerating approach produces noise levels slightly lower than the standard 3 degree approach throughout all of the approach flight path (20-knot decrease curve).

8.2.2 VSCE 502B Configuration - For the VSCE 502B configuration, Figure 24 reveals that takeoff without cutback generally provides lower community noise levels except in the vicinity of a monitor near the airport. Again, the two cutbacks at altitudes of 213 m (700 ft) and 335 m (1100 ft) permit the aircraft to meet FAR Part 36 noise levels, while the other flight paths studied do not. By leveling off at 1.5 km (5000 ft) and increasing speed, it is possible to decrease the aircraft noise at large distances from brake release at the expense of an increase in noise level after leveling off (see Figure 24, cutback at 1300 ft curve). The more rapid decrease at large

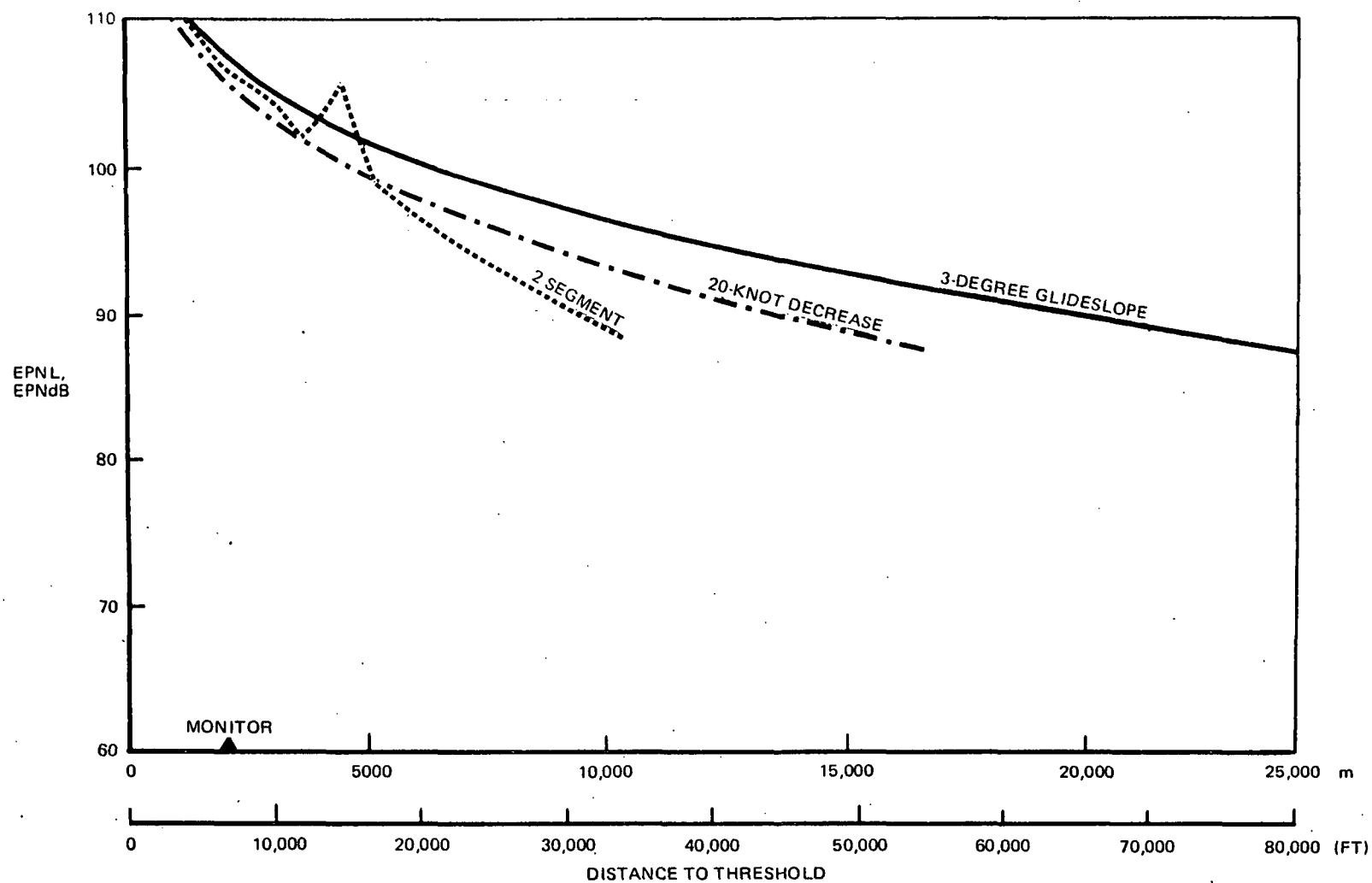


FIGURE 23. ESTIMATED APPROACH CENTERLINE NOISE LEVELS – MDC TURBOJET AIRCRAFT

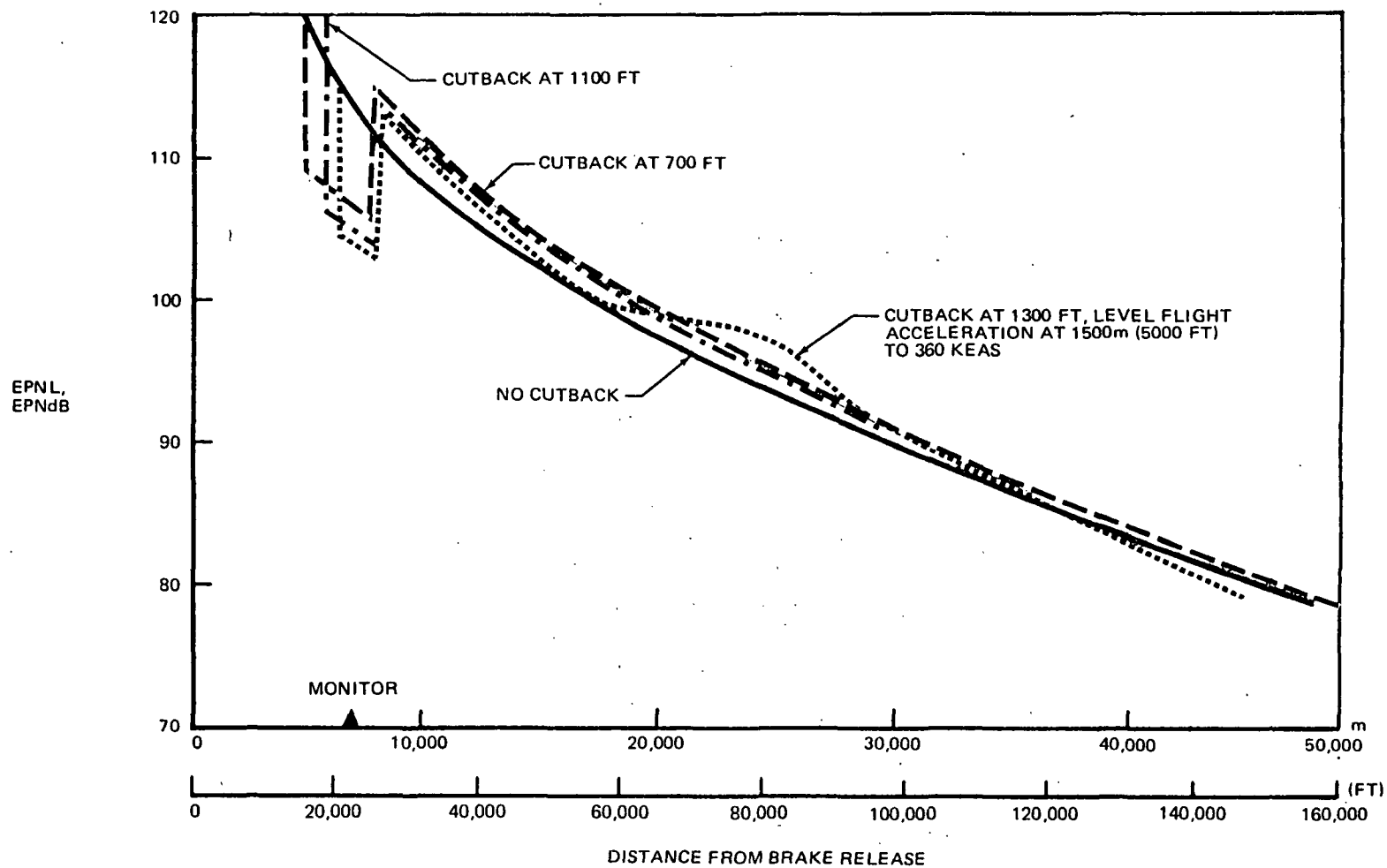


FIGURE 24. ESTIMATED TAKEOFF CENTERLINE NOISE LEVELS — VSCE 502B CONFIGURATION

distances is due to a better climb gradient at the higher aircraft speed.

Of the three approach procedures studied, the two segment approach produces the lowest noise levels at distances greater than 5000 m (16,404 ft) from the threshold for the VSCE 502B configuration (Figure 25). The noise level increases during the transition from the 6 degree to the 3 degree glideslope due to an engine thrust transient. The decelerating approach produces noise levels lower than the standard 3 degree approach throughout the approach flight path. The VSCE 502B configuration noise levels are slightly lower than the MDC turbojet airplane during approach.

8.2.3 DC-8-61 Aircraft - The DC-8-61 noise levels directly beneath the takeoff flight path are shown in Figure 26. The noise levels for the typical mission aircraft, 108,637 kg (239,500 lbs) are significantly lower than for the maximum gross weight aircraft, 147,420 kg (325,000 lbs) throughout the flight path. The inflection in the noise level curve between 5000 and 10,000 m (16,404 and 32,808 ft) is caused by the decrease in engine thrust from takeoff to maximum climb thrust. The more rapid decrease in noise levels after 15,000 m (49,212 ft) from brake release for the light gross weight aircraft is caused by a resumption in climbing after the aircraft was cleaned up at an altitude of 914 m (3000 ft). The heavier gross weight aircraft is not in a clean configuration until after 25,000 m (82,021 ft) from brake release.

8.3 Community Noise Contours

8.3.1 MDC Turbojet Aircraft - Figure 27 shows the contours for the seven takeoff flight paths studied for the MDC turbojet aircraft. The 2-segment approach procedure causes the 90 EPNdB contour to form closest to the runway threshold. However, the decelerating approach causes the 100 EPNdB contour to form closer to the threshold. For takeoff, the full power takeoff procedure produces the shortest distance to closure for all contour levels (90, 100, and 110 EPNdB) and all flight procedures studied.

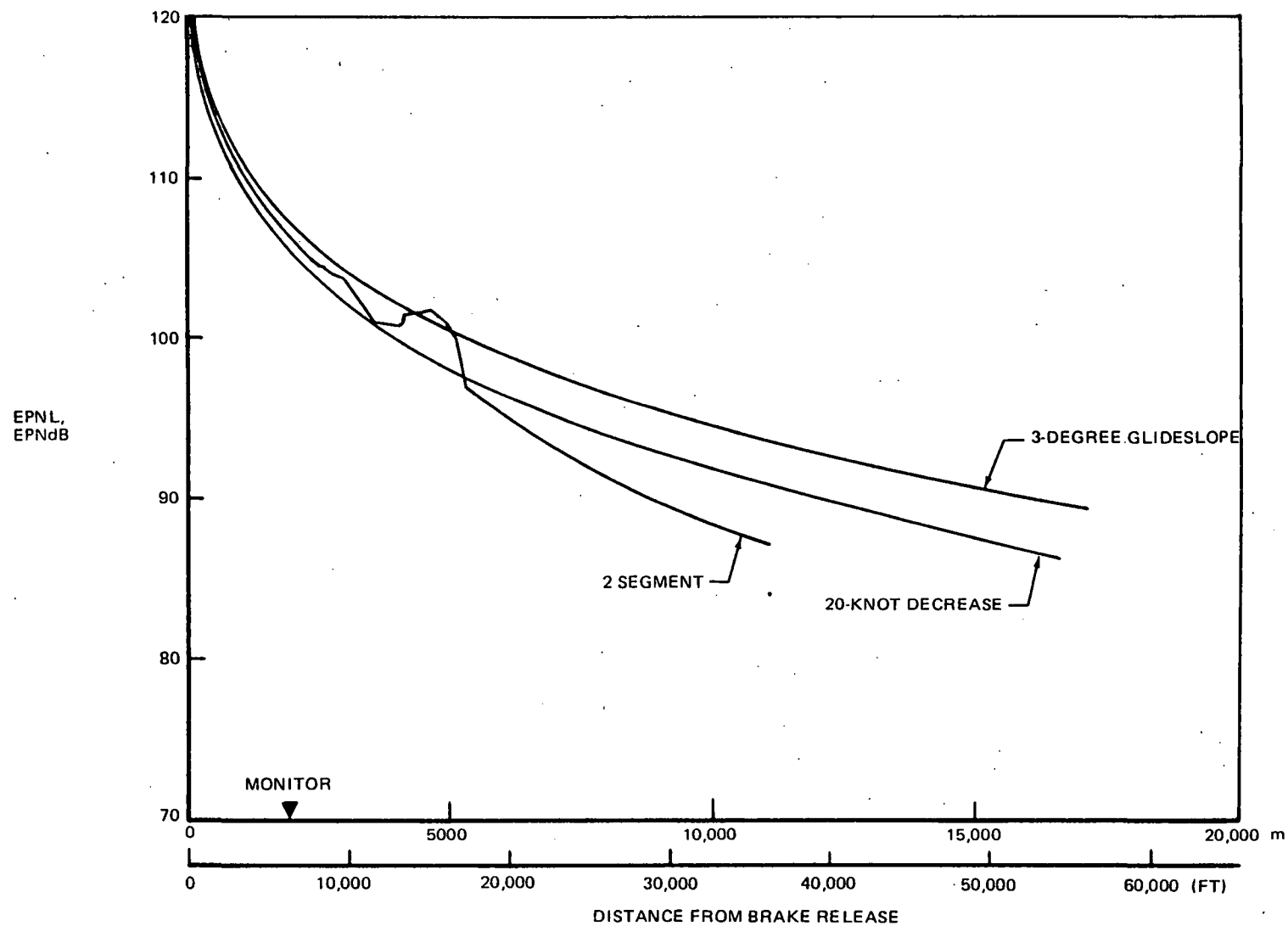


FIGURE 25. ESTIMATED APPROACH CENTERLINE NOISE LEVELS – VSCE 502B CONFIGURATION

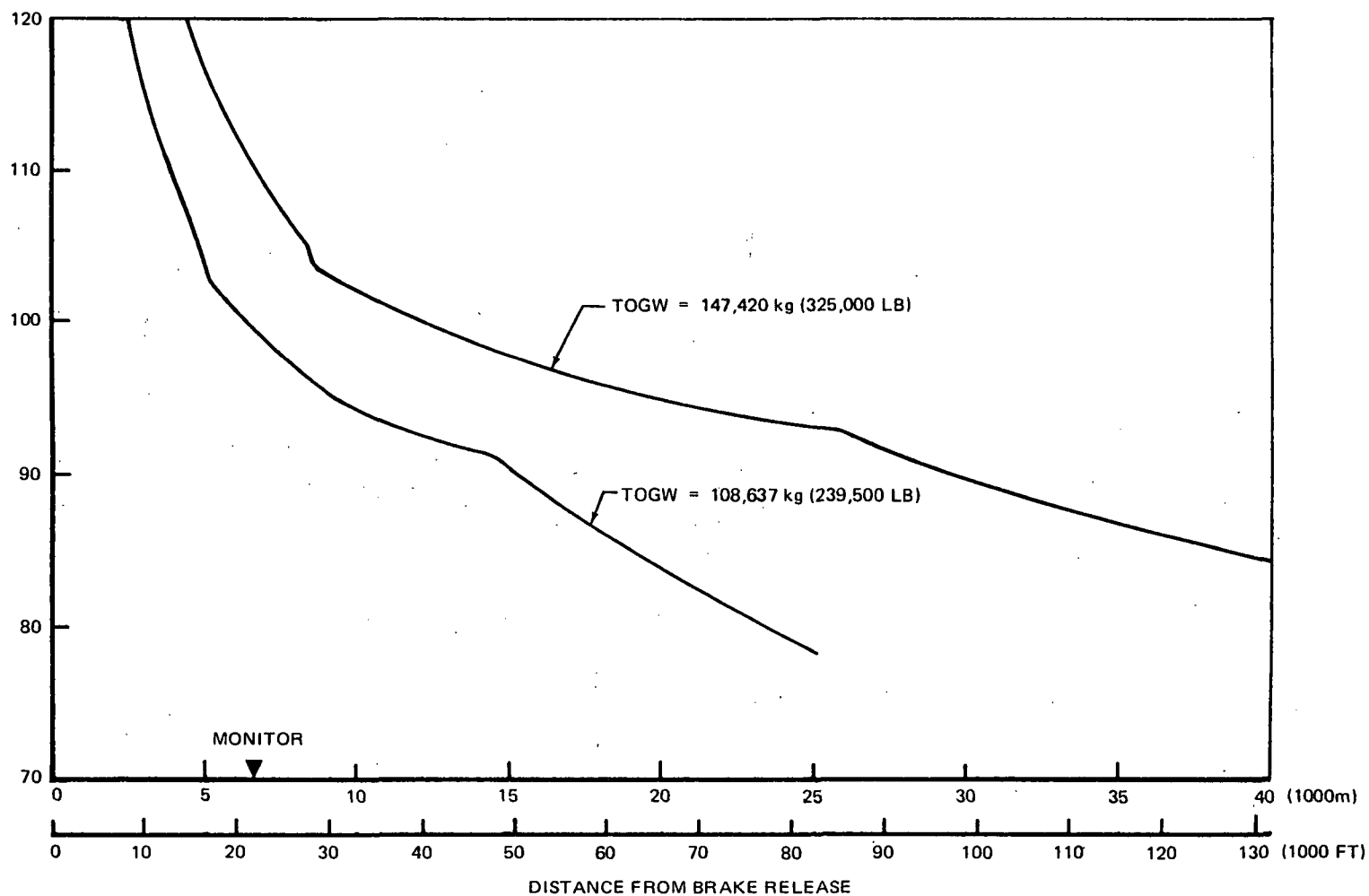
EPNL,
EPNdB

FIGURE 26. ESTIMATED TAKEOFF CENTERLINE NOISE LEVELS — DC-8-61/JT3D-3B

APPROACH

TAKEOFF

PROCEDURE NO.

20 KN DECELERATING

CUTBACK AT 213m (700 FT), MAX SUPPRESSED
POWER AFTER MONITOR

EPNdB LEVELS

110

100

90

3

5000m
(16,400 FT)

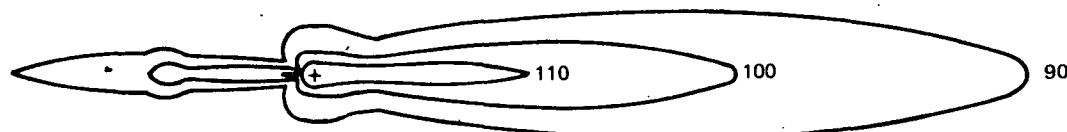
NOTE:

STUDY PROCEDURES ILLUSTRATE THE
VARIANCE BETWEEN FLIGHT PROCEDURES
TO MEET NOISE LEVEL REQUIREMENTS AT
MONITORS NEAR THE AIRPORT AND THOSE
TO ALLEVIATE COMMUNITY NOISE.



CUTBACK AT 335m (1100 FT), MAX SUPPRESSED
POWER AFTER MONITOR

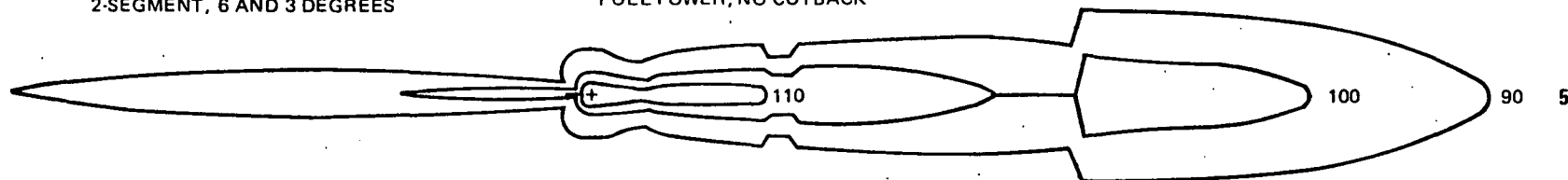
4



2-SEGMENT, 6 AND 3 DEGREES

FULL POWER, NO CUTBACK

1



3-DEGREE GLIDESLOPE

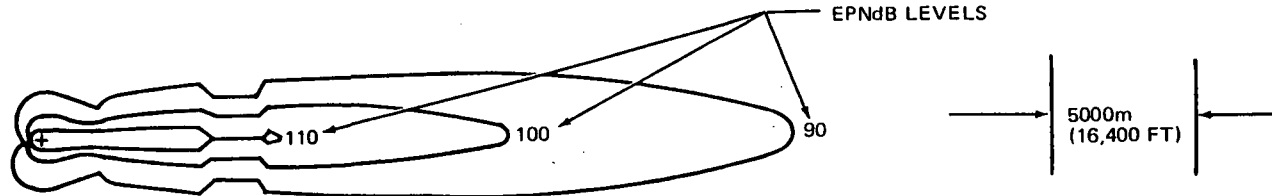
CUTBACK 3 SECONDS BEFORE MONITOR, MAX SUPPRESSED POWER
TO 1500m (5000 FT), CLEAN UP, STOW SUPPRESSORS, ACCELERATE
TO 360 KEAS AT MAXIMUM CLIMB POWER

5

FIGURE 27. ESTIMATED COMMUNITY NOISE CONTOURS FOR SEVERAL TAKEOFF FLIGHT PATHS -
MDC TURBOJET AIRCRAFT

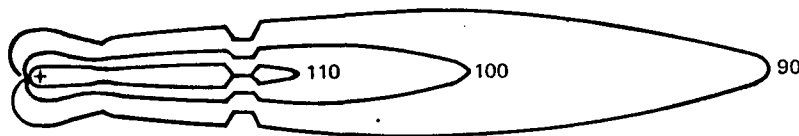
TAKEOFF

PROCEDURE NO.



6

V₂ HELD PAST MONITOR, CUTBACK AT 335m (1100 FT), MAXIMUM SUPPRESSED POWER AFTER MONITOR

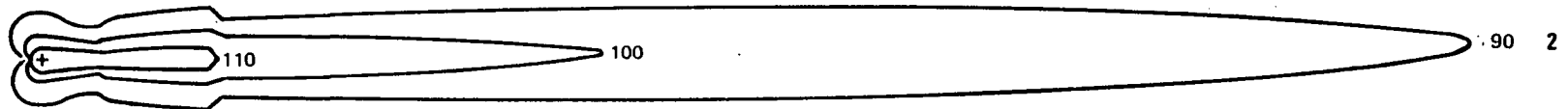


NOTE:

STUDY PROCEDURES ILLUSTRATE THE VARIANCE BETWEEN FLIGHT PROCEDURES TO MEET NOISE LEVEL REQUIREMENTS AT MONITORS NEAR THE AIRPORT AND THOSE TO ALLEVIATE COMMUNITY NOISE.

7

MAXIMUM ACCELERATION PRIOR TO MONITOR, CUTBACK 3 SECONDS BEFORE MONITOR, MAXIMUM SUPPRESSED POWER AFTER MONITOR



2

CUTBACK AT 335m (1100 FT), CLIMB AT CUTBACK POWER

FIGURE 27. (CONTINUED) ESTIMATED COMMUNITY NOISE CONTOURS FOR SEVERAL TAKEOFF FLIGHT PATHS – MDC TURBOJET AIRCRAFT

The abrupt changes in the width of the contours are caused by decreases or increases in engine power. The large bulge at the right end of the procedure 5 contour in Figure 27 is caused by retraction of the noise suppressors and an increase in engine power. The procedure 2 contour in Figure 27 shows that the 90 and 100 EPNdB noise contour is extended due to the reduced climb gradient resulting from cutback power. This takeoff procedure produces larger contour areas than any of the other suppressed takeoff procedures studied.

8.3.2 VSCE 502B Configuration - Figure 28 shows the contours for the four flight paths studied for the VSCE 502B configuration. The 2-segment approach produces the shortest contour at the 90 EPNdB level, but the decelerating approach provides the shortest contour at the 100 EPNdB level. The full power takeoff procedure produces the shortest contour of all the flight procedures studied. The abrupt changes in the width of the contours are caused by decreases or increases in engine power.

The takeoff and approach procedures that conform to FAR Part 36 rules have been used to compare 90, 100, and 110 EPNdB community noise contours for both supersonic aircraft. The results, including contour areas, are presented in Figures 29 and 30 for the MDC turbojet and the VSCE 502B aircraft, respectively. Figure 31 compares the 90 EPNdB noise contours for the MDC turbojet and the VSCE 502B aircraft at constant maximum takeoff gross weights. Both aircraft are flown using the same procedures. The MDC turbojet aircraft produces the smaller contour area.

8.3.3 DC-8-61 Aircraft - Figure 32 presents the results for the DC-8-61 aircraft operated at maximum takeoff and landing gross weights. Figure 33 shows the results for the aircraft operated on a typical mission [1850 kilometers (1000 n.mi.) at a 60 percent load factor].

8.3.4 Contour Areas - The takeoff contour areas, for the MDC turbojet and VSCE 502B configurations, are summarized in Table 6 and the approach contour areas in Table 7. Table 6 shows that for both SCAR configurations, the full power takeoff without cutback gives the minimum (or near minimum)

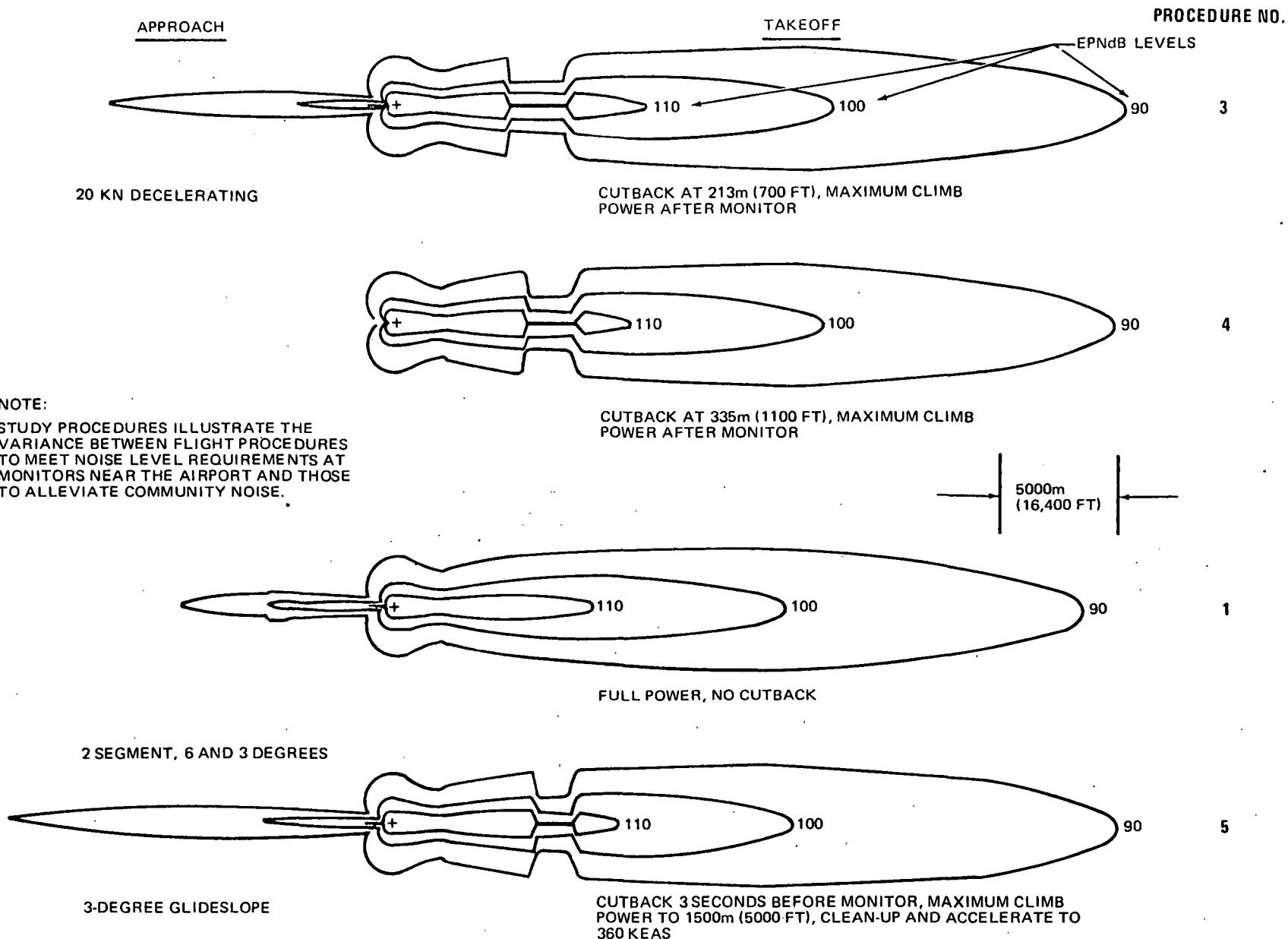


FIGURE 28. ESTIMATED COMMUNITY NOISE CONTOURS FOR SEVERAL TAKEOFF FLIGHT PATHS - VSCE 502B CONFIGURATION

TOGW = 340,194 kg (750,000 LB)
 TAKEOFF FLIGHT PATH = CUTBACK AT 335m (1100 FT)
 LANDING FLIGHT PATH = 2-SEGMENT APPROACH

NOTE:

STUDY PROCEDURES ILLUSTRATE THE
 VARIANCE BETWEEN FLIGHT PROCEDURES
 TO MEET NOISE LEVEL REQUIREMENTS AT
 MONITORS NEAR THE AIRPORT AND THOSE
 TO ALLEVIATE COMMUNITY NOISE.

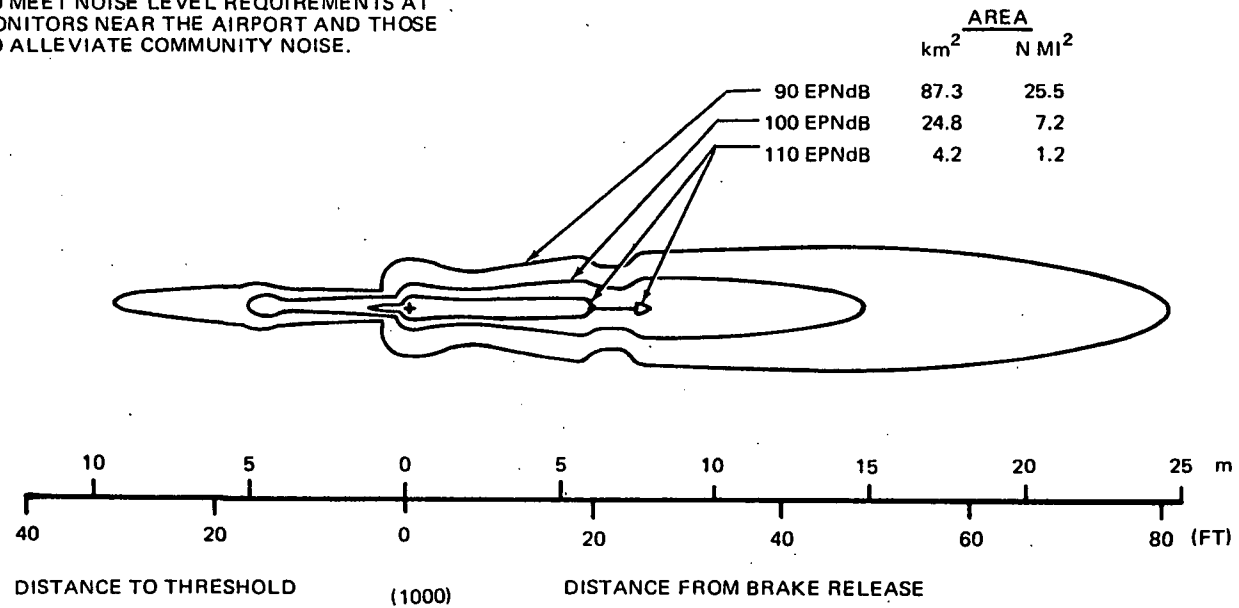


FIGURE 29. ESTIMATED NOISE CONTOURS – MDC TURBOJET AIRCRAFT

TOGW = 340,194 kg (750,000 LB)
 TAKEOFF FLIGHT PATH = CUTBACK AT 335m (1100 FT)
 LANDING FLIGHT PATH = 2-SEGMENT APPROACH

NOTE:

STUDY PROCEDURES ILLUSTRATE THE
 VARIANCE BETWEEN FLIGHT PROCEDURES
 TO MEET NOISE LEVEL REQUIREMENTS AT
 MONITORS NEAR THE AIRPORT AND THOSE
 TO ALLEVIATE COMMUNITY NOISE.

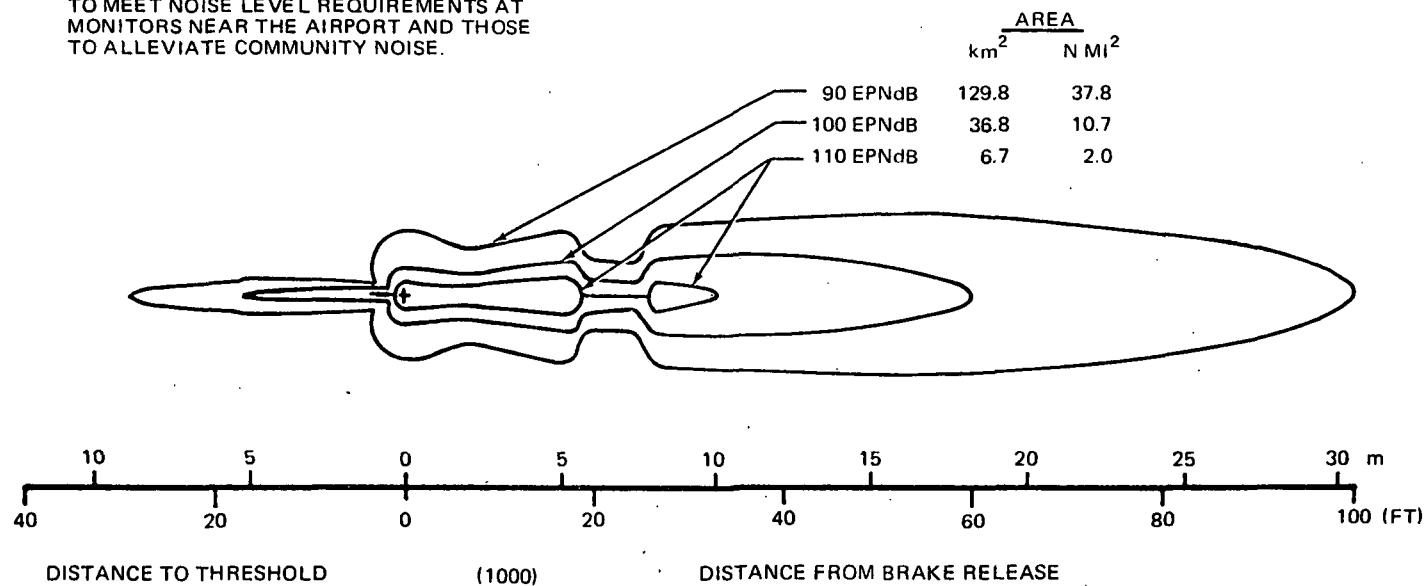


FIGURE 30. ESTIMATED NOISE CONTOURS – VSCE 502B CONFIGURATION

NOTE:

STUDY PROCEDURES ILLUSTRATE THE VARIANCE BETWEEN FLIGHT PROCEDURES TO MEET NOISE LEVEL REQUIREMENTS AT MONITORS NEAR THE AIRPORT AND THOSE TO ALLEVIATE COMMUNITY NOISE.

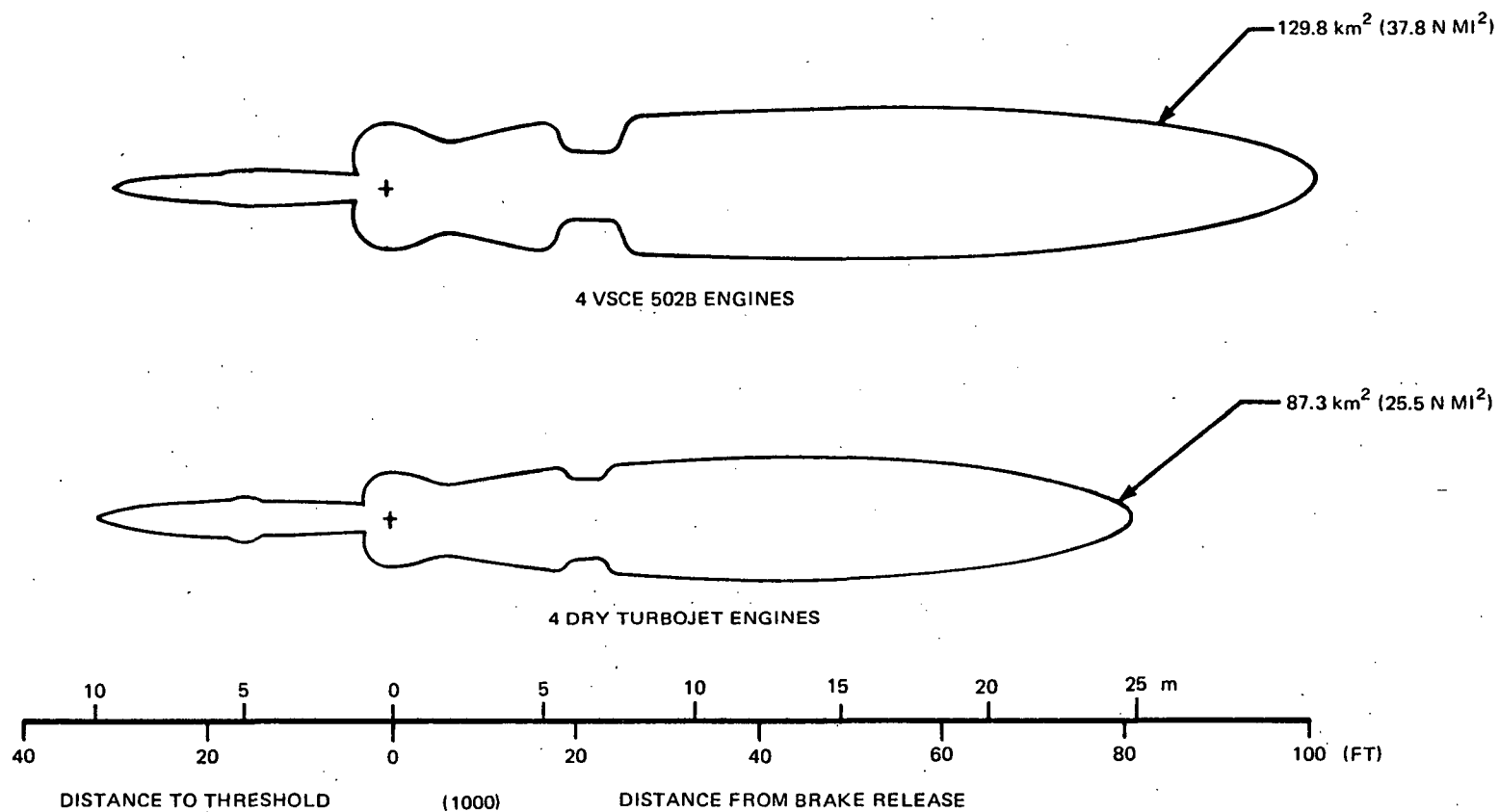


FIGURE 31. COMPARISON OF 90 EPNdB ESTIMATED NOISE CONTOURS FOR THE STUDY SUPERSONIC AIRCRAFT

TOGW = 147,420 kg (325,000 LB)
 LDGW = 108,864 kg (240,000 LB)
 TAKEOFF FLIGHT PATH = TAKEOFF THRUST TO 457m (1500 FT) REDUCE TO
 MAX CLIMB THRUST, CLEAN-UP AT 914m (3000 FT)
 LANDING FLIGHT PATH = STANDARD 3-DEG APPROACH

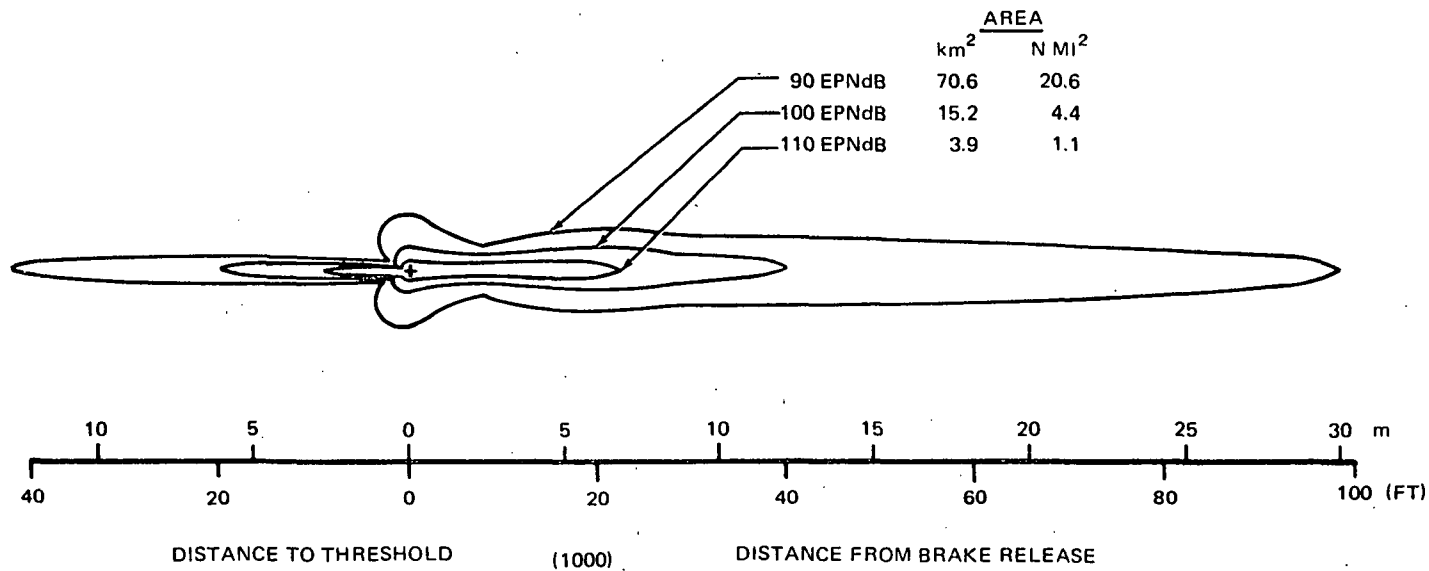


FIGURE 32. ESTIMATED NOISE CONTOURS – DC-8-61 AIRCRAFT, MAXIMUM TAKEOFF GROSS
 WEIGHT MISSION

TOGW = 108,637 kg (239,500 LB)
 LDGW = 95,314 kg (210,130 LB)
 TAKEOFF FLIGHT PATH = TAKEOFF THRUST TO 457m (1500 FT), REDUCE TO
 MAXIMUM CLIMB THRUST, CLEAN-UP AT 914m (3000 FT)
 LANDING FLIGHT PATH = STANDARD 3-DEGREE APPROACH

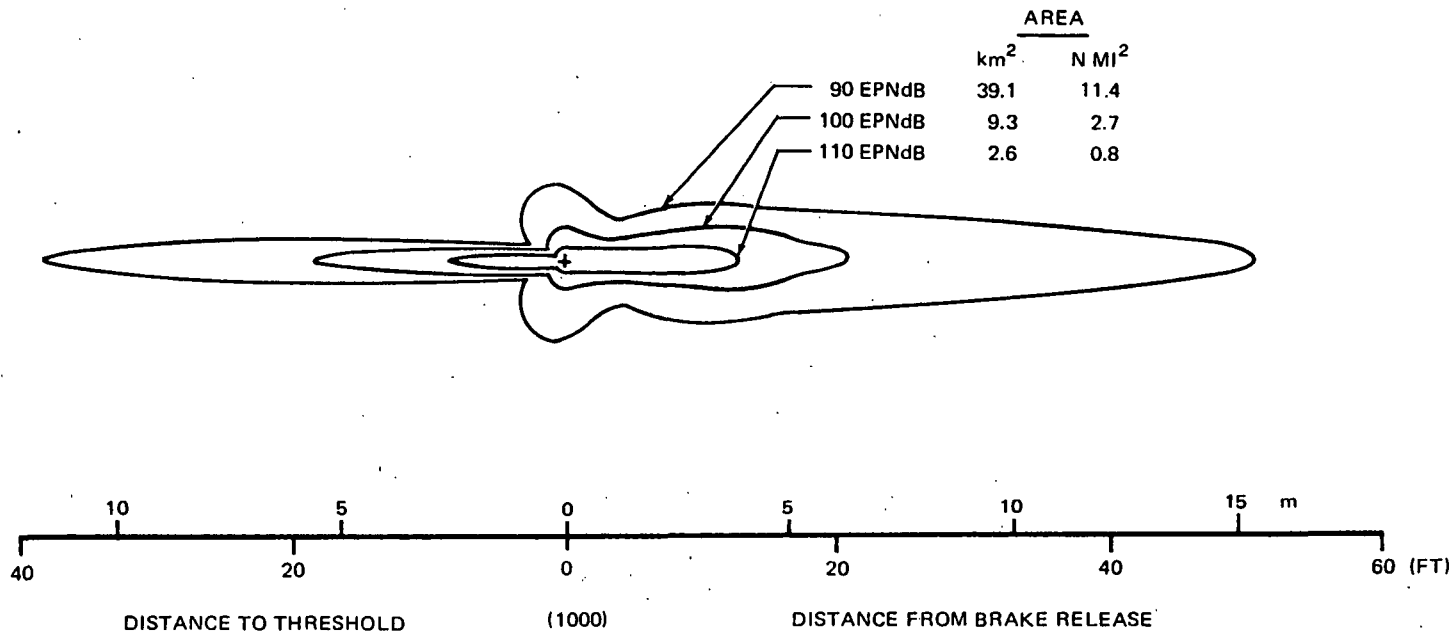


FIGURE 33. ESTIMATED NOISE CONTOURS – DC-8-61 AIRCRAFT, TYPICAL MISSION TAKEOFF GROSS WEIGHT

areas within the 90 EPNdB and 100 EPNdB single event noise level contours, but not within the 110 EPNdB contour. Table 7 shows that the minimum 90 EPNdB approach contour area is achieved with a 2-segment approach for both SCAR aircraft, but the minimum areas for the 100 EPNdB and 110 EPNdB contours are achieved with the decelerating approach. However, the difference in areas between the decelerating approach and the 2-segment approach at the 100 EPNdB and 110 EPNdB noise levels is not large [$< .7 \text{ km}^2$ ($.2 \text{ n.mi.}^2$)].

From Table 6, one can compare the relative areas within selected takeoff contours at given noise levels for the two SCAR aircraft. The contour areas for the VSCE engine powered configuration are greater than the corresponding areas for the MDC turbojet configuration for all cases except the one which retracts the suppressor at 1500 m (5000 ft). Thus, with the cutback procedures in conformance with the current FAR Part 36 regulations, the contour areas for the MDC turbojet are approximately 63 percent of the corresponding areas for the VSCE configuration. The range of the VSCE configuration is significantly greater than the range of the MDC turbojet configuration. If the ranges of the two SCAR configurations were made equivalent, then resizing the VSCE airplane and engine to smaller sizes can be accomplished. The resulting contour area for the VSCE configuration could possibly be reduced.

Table 8 shows that the contour areas for the DC-8-61 aircraft operating on a typical mission are less than the corresponding contour areas for the aircraft operating at maximum takeoff gross weight. The above result is particularly important when considering the community noise impact of potential future supersonic cruise aircraft. It should be recalled that all of the community noise contours presented for the two supersonic cruise configurations are for takeoff and landing at maximum gross weight. Thus, consideration of a typical mission for the supersonic aircraft leads to a potential reduction in the contour area at any given level from that shown herein.

The change in contour area due to various operational procedures does not represent a true change in community noise annoyance since much of the higher contour area (100 and 110 EPNdB) lies within the airport boundary. The

TABLE 6
SUPERSONIC CRUISE CONFIGURATION TAKEOFF CONTOUR AREAS
CONTOUR AREA, km² (n.mi.²)

PROCEDURE NUMBER	PROCEDURES	MDC TURBOJET			VSCE CONFIGURATION		
		90 EPNdB	100 EPNdB	110 EPNdB	90 EPNdB	100 EPNdB	110 EPNdB
1	FULL POWER	75.27 (21.94)	21.45 (6.25)	4.27 (1.24)	122.14 (35.61)	34.84 (10.16)	7.56 (2.20)
3	CUTBACK AT 213 m (700 ft)	78.50 (22.88)	22.82 (6.65)	4.14 (1.21)	123.91 (36.13)	35.75 (10.42)	6.79 (1.98)
4	CUTBACK AT 335 m (1100 ft)	78.50 (22.88)	22.61 (6.59)	4.01 (1.17)	122.87 (35.82)	35.22 (10.27)	6.63 (1.93)
5	CUTBACK AT 395 m (1300 ft) SUPPRESSOR RETRACTED AT 1500 m (5000 ft), CLIMB AT MAXIMUM UNSUPPRESSED POWER	124.84 (36.40)	38.62 (11.26)	4.17 (1.22)	123.40 (35.98)	33.70 (9.83)	6.92 (2.02)
6	CUTBACK AT 335 m (1100 ft) WITH AIRCRAFT SPEED HELD AT V ₂ , CLIMB AT MAXIMUM SUPPRESSED POWER	79.18 (23.08)	23.41 (6.83)	3.86 (1.13)			
2	CUTBACK AT 335 m (1100 ft) SPEED AT V ₂ + 10 KNOTS, CLIMB AT 4% GRADIENT	123.34 (35.96)	21.76 (6.34)	3.96 (1.15)			
7	CUTBACK 3 SEC BEFORE MONITOR, AIRCRAFT SPEED MAXIMUM PRIOR TO MONITOR [V ₂ + 37 KNOTS], CLIMB AT MAXIMUM SUPPRESSED POWER	72.60 (21.17)	20.44 (5.96)	4.58 (1.34)			

TABLE 7
SUPERSONIC CRUISE CONFIGURATION APPROACH CONTOUR AREAS

<u>PROCEDURE</u>	CONTOUR AREA, km^2 (n.mi. ²)					
	<u>MDC TURBOJET</u>			<u>VSCE CONFIGURATION</u>		
	<u>90 EPNdB</u>	<u>100 EPNdB</u>	<u>110 EPNdB</u>	<u>90 EPNdB</u>	<u>100 EPNdB</u>	<u>110 EPNdB</u>
STANDARD (3°)	23.13 (6.74)	2.49 (0.73)	.13 (.04)	15.23 (4.44)	1.68 (0.49)	.10 (.03)
2 SEGMENT (6°) and (3°)	8.78 (2.56)	2.28 (0.67)	.13 (.04)	6.92 (2.01)	1.53 (0.45)	.10 (.03)
20 KEAS DECELERATING APPROACH	12.51 (3.65)	1.58 (0.46)	.08 (.02)	9.30 (2.71)	1.11 (0.32)	.08 (.02)

TABLE 8
DC-8-61 COMMUNITY NOISE CONTOUR AREAS

<u>TAKEOFF GROSS WEIGHT</u>	<u>LANDING GROSS WEIGHT</u>	CONTOUR AREAS, km ² (n.mi ²)		
		<u>90 EPNdB</u>	<u>100 EPNdB</u>	<u>110 EPNdB</u>
147,147 kg (325,000 LB)	108,862 kg (240,000 LB)	70.6 (20.6)	15.2 (4.4)	3.9 (1.1)
108,635 kg* (239,500 LB)	96,674 kg (213,130 LB)	39.1 (11.4)	9.3 (2.7)	2.6 (0.8)

*Takeoff with the ATA noise abatement cutback procedure

population density around airports is not uniform. Therefore, the true impact on community noise of the various contour levels or areas can best be evaluated by analyzing the population density around a specific airport and determining the relative number of people exposed and annoyed based on a noise exposure forecast (NEF). This type of investigation was beyond the present study contract.

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